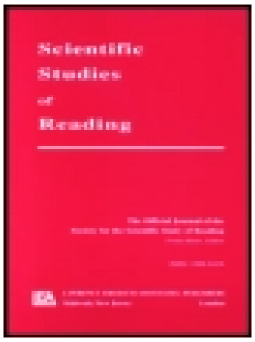

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Readers Recruit Executive Functions to Self-Correct Miscues during Oral Reading Fluency

Tin Q Nguyen[a], Stephanie N Del Tufo[b], and Laurie E. Cutting[a]

[a]Vanderbilt Kennedy Center, Peabody College of Education and Human Development, Vanderbilt Brain Institute, Vanderbilt University, Nashville, Tennessee, USA; [b]College of Education and Human Development, University of Delaware, Newark, Tennessee, USA

ABSTRACT

Reading fluency undoubtedly underlies reading competence; yet, the role of executive functions (EFs) is less well understood. Here, we investigated the relation between children's reading fluency and EF. Children's (n = 82) reading and language performance was determined by standardized assessments and EF by parental questionnaire. Results revealed that the production of more miscues was explained by poorer reading and language performance and EF. Yet, self-correcting a miscue was predicted by better EF, beyond reading and language abilities. Intriguingly, EF partially mediated the relation between reading and self-correction, suggesting that self-correction reflects parallel recruitment and coordination of domain-specific and domain-general processes.

Introduction

Children develop reading competence by mastering word recognition and text comprehension (Hoover & Gough, 1990; Scarborough, 2001). One hallmark sign of a proficient reader is reading fluency, or automatic and accurate word recognition (decoding), resulting in successful comprehension (Fuchs, Fuchs, Hosp, & Jenkins, 2001; LaBerge & Samuels, 1974; Perfetti, 1985; Rasinski & Hoffman, 2003). Fluent reading allows readers to dedicate their attention to the more cognitively taxing task of comprehension, rather than decoding individual words (Eason, Sabatini, Goldberg, Bruce, & Cutting, 2013; Nathan & Stanovich, 1991). Thus, reading difficulties may be traced back to readers struggling to process text fluently.

Historically, oral reading fluency (ORF) has been defined in one of two ways. The first is more straightforward and is simply how fast and accurately text is read (number of words per minute; or number of words correctly read per minute [WCPM]) (Fuchs et al., 2001). Other definitions view ORF as a multicomponential construct that taps an interactive system between lower- and higher-level reading and language abilities (Fuchs et al., 2001; Kuhn, Schwanenflugel, & Meisinger, 2010; Stanovich, 1980). An additional consideration is whether ORF is measured at word versus passage levels. This distinction is important as ORF for isolated words overlaps with ORF in passages (ORF-P); yet, ORF-P explains substantially more variance in comprehension (Eason et al., 2013; Jenkins, Fuchs, van den Broek, Epsin, & Deno, 2003b; Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003a; Klauda & Guthrie, 2008). That is, ORF-P may capture some higher-level cognitive processes involved in comprehension.

Here, we focus on ORF-P to understand readers' cognitive characteristics in relation to oral reading errors (miscues) and self-corrections when surrounding contextual information is available. Miscues include mispronunciations, additions, transpositions, repetitions, and omissions (Leslie &

CONTACT Laurie E. Cutting laurie.cutting@vanderbilt.edu Vanderbilt University, PMB 40, 230 Appleton Place, Nashville, TN 37203, USA.

Caldwell, 2011). The ability to self-correct is unique in that it signifies that the reader has both detected *and* corrected a reading error (Chinn, Waggoner, Anderson, Schommer, & Wilkinson, 1993; Frederiksen, 1981a, 1981b; Fuchs et al., 2001; Katzir et al., 2006; Recht, 1976). While studies have investigated the impact of miscues on reading performance, none have examined how readers' characteristics may influence self-corrections (Abbott, Wills, Miller, & Kaufman, 2012; Shaul, Katzir, Primor, & Lipka, 2016). Specifically, a set of domain-general, higher-level cognitive abilities known as executive functions (EFs) have been hypothesized, and shown to some extent, to support ORF-P (Fuchs et al., 2001; Jenkins et al., 2003a; Mahone, Koth, Cutting, Singer, & Denckla, 2001; Miller et al., 2014; Spencer et al., 2018; Stanovich, 1980; Wolf & Katzir-Cohen, 2001). Yet, EF has yet to be formally evaluated in relation to miscues and self-corrections.

Reading and language skills associated with ORF-P

Various reading and language processes contribute to ORF-P. Perhaps the most basic is the ability to recognize and sound out, or decode, words (Fuchs et al., 2001). Phonological awareness, the ability to distinguish and access constituent sounds of words (Liberman, Shankweiler, & Liberman, 1989), is predictive of decoding and, thus, not surprisingly, associated with ORF-P (Bradley & Bryant, 1983; Norton & Wolf, 2012; Snowling, 1998; Wagner & Torgesen, 1987). Proficient phonological awareness skills allow readers to attend to and segment sound units of printed words while reading aloud (Anthony & Francis, 2005; Hoover & Gough, 1990). As such, proficient phonological awareness skills, and consequently strong decoding skills, allow for efficient ORF-P. Hence, reading skills at the word level underlie ORF-P.

Beyond its bottom-up components, ORF-P also depends on oral language skills. Fluent decoding relies not only on effective coupling of orthographic and phonological information but also on readers' semantic knowledge of the words, as well as sensitivity to sentence and passage structures (Ehri, 2005; Fuchs et al., 2001; Hudson, Pullen, Lane, & Torgesen, 2008; Pilkulski & Chard, 2005). Additionally, when reading passages, top-down language components (semantics and syntax) interact with bottom-up skills to facilitate word reading within a meaningful context (Klauda & Guthrie, 2008; Rasinski, 1985; Torgesen, Rashotte, & Alexander, 2001). Hence, the ease with which one decodes words, processes meaning, and constructs a semantic interpretation of a text accounts for ORF-P variance.

Overall, to achieve proficient ORF-P, readers must be capable of coordinating multiple reading and language processes. This complex orchestration may require additional skills beyond those within the linguistic realm to render effective ORF-P. (Berninger, Abbott, Billingsley, & Nagy, 2001; Fuchs et al., 2001; Mahone et al., 2001; Perfetti, 1985; Stanovich, 1980; Wolf & Katzir-Cohen, 2001). Thus, EF has been suggested as a key, interactive player in fluent reading.

The role of EF in reading and language skills and ORF-P

EF is a constellation of domain-general cognitive skills subserved by the prefrontal cortex. While there are various models of EF, most include working memory, monitoring, task-shifting (or cognitive flexibility; Deak, 2003), and inhibition (Diamond, 2013; Lyons & Zelazo, 2011; Miyake et al., 2000). While there is scant empirical support for the involvement of EF in ORF-P, the reading and language skills known to support ORF-P have been shown to tap EF (Altemeier, Abbott, & Berninger, 2008; Berninger et al., 2001; Bowey, 1986; Cirino et al., 2018; Cutting, Materek, Cole, Levine, & Mahone, 2009; Sesma, Mahone, Levine, Eason, & Cutting, 2009; Locascio, Mahone, Eason, & Cutting, 2010). For example, limited working memory has been linked to impairment in word-level skills, such as decoding and phonological awareness (Altemeier et al., 2008; Georgiou, Das, & Hayward, 2008). Other EF components, such as monitoring and inhibition, have been related to identifying and/or suppressing irrelevant information (Bub, Masson, & Lalonde, 2006; Cain, 2006; Chiappe, Hasher, & Siegel, 2000; Kieffer, Vukovic, & Berry, 2013), allowing readers to draw inferences and build a coherent mental representation of the written text (Cain, Oakhill, & Bryant, 2004a; Cooke, Halleran, & O'Brien, 1998). Having a coherent mental representation of the text, in turn, facilitates decoding through lexical retrieval and the spreading of semantic activation (Barth, Tolar, Fletcher, & Francis, 2014; Cain, Oakhill, & Lemmon, 2004b; Van den Broek, Rapp, & Kendeou, 2005).

Beyond its role in reading and language skills, EF likely operates by coordinating these processes to harmonize fluent reading (Cole, Duncan, & Blaye, 2014; Fuchs et al., 2001; Hudson et al., 2008; Perfetti, 1985; Stanovich, 1984). Working memory and task-shifting would be critical in promoting automaticity in reading and language skills, allowing for allocation of attentional resources to other higher-order tasks, such as semantic retrieval and integration (Logan, 1997; Perfetti, 1985; see also Cartwright, 2012; Cole et al., 2014; Deak, 2003; Meixner, Warner, Lensing, Schiefele, & Elsner, 2019). Other EF components, including monitoring and inhibition, may assist with the efficient communication between lower- and higher-order processes during ORF-P (Berninger et al., 2001; Wolf, Bowers, & Biddle, 2000). Taken together, readers need to recruit multi-layered components of the overall reading framework for proficient ORF-P, whereby EF necessarily orchestrates this complex interplay (Berninger et al., 2001; Klaus, Madebach, Opperman, & Jescheniak, 2017; Pilkulski & Chard, 2005; Storch & Whitehurst, 2002; Wolf & Katzir-Cohen, 2001). Given the role of EF in reading and language skills, it seems evident that skilled ORF-P taps EF. Yet, whether EF underlies other components of ORF-*P* – miscues and self-corrections – remains unknown.

Miscues and self-corrections in ORF-P

Prior research has largely focused on reading rate and/or accuracy as indices for ORF-P to be examined in relation to reading and language skills (Fuchs et al., 2001). Yet, several reports (e.g., Abbott et al., 2012; Chinn et al., 1993; Labov & Baker, 2010) suggest that evaluating miscues could shed further light on the multicomponential nature of ORF-P.

Miscues

Miscues are associated with reading impairments. Difficulties with ORF-P and online comprehension may elicit a cascading production of miscues partially due to interrupted mental representation of the passage contents (Abbott et al., 2012; Kucer, 2009, 2016; Pflaum & Bryan, 1980; Posner & Synder, 1975; see also Meyer & Felton, 1999; Plaut, 1999; Rasinski, 2003). Readers who encounter challenges mastering decoding likely produce more miscues (Elleman, Steacy, Olinghouse, & Compton, 2017; Paige et al., 2018; see also Rasinski & Hoffman, 2003). Throughout the stages of reading acquisition, miscues additionally reveal a reliance on contextual facilitation (Stanovich, 1984; Torgesen et al., 2001). That is, readers must integrate the decoded words within the context of a coherent sentence (and often within larger passage context) to reduce the chances of producing a miscue. Not surprisingly, as compared to their skilled peers, poor readers experience difficulties with coordinating cognitive skills across word, sentence, and passage levels in ORF-P (Berninger et al., 2001; Farmer & Klein, 1995; Klauda & Guthrie, 2008; Leu, 1982, Swanson & Ashbaker, 2000; Wang & Gathercole, 2013). These difficulties also tax EF (Cain et al., 2004a, 2004b; Engelhardt, Nigg, & Ferreira, 2013; Perfetti, Marron, & Foltz, 1996; Shankweiler, 1999; Stanovich, Cunningham, & Feeman, 1984; Swanson & O'Connor, 2009; Wolf & Katzir-Cohen, 2001). Thus, within this framework, miscues would in part stem from multicomponential failure (Hudson, Pullen, Lane, & Torgesen, 2008; Wolf & Katzir-Cohen, 2001), including executive dysfunction. Nevertheless, despite miscues, some readers remain able to maintain the integrity of their reading performance via post-lexical, comprehension-monitoring strategies, such as self-correction (Oakhill, Hartt, & Samols, 2005; Paris & Myers, 1981; see also Andrews, 1996; Bowey, 1986; D'Angelo, 1982; Hudson et al., 2008; Seidenberg, Waters, Sanders, & Langer, 1984; Tunmer & Bowey, 1984). As such, understanding the cognitive characteristics underpinning reading difficulties and strategies may provide insights for further research and interventions.

Self-corrections

In contrast to miscues, self-corrections signify that the reader has actively noticed *and* corrected a reading error. Additionally, the particular role of self-corrections has been hypothesized to fall in line with the multicomponential nature of ORF-P (Clay, 1969; Forbes, Poparad, & McBride, 2004; Pratt & Urbanowski, 2015; see also Chinn et al., 1993; Fuchs et al., 2001; Jenkins et al., 2003b). That is, miscues reflect readers' impairments in various cognitive skills. Self-corrections, in contrast, are postulated to tap readers' ability to leverage surrounding textual and contextual cues (Forbes et al., 2004). While self-corrections are thought to highlight the ability to handle textual and contextual discrepancies, less is understood as to *how* this occurs. Several reports have argued that self-corrections may map onto readers' parallel recruitment of domain-specific *and* domain-general processes (i.e., reading- and language-related skills *and*, potentially, EF) to resolve miscues and maintain fluency (Fuchs et al., 2001; Jenkins et al., 2003b; Katzir et al., 2006; see also D'Angelo, 1981; Deak, 2003; Leu, 1982; McGee, Kim, Nelson, & Fried, 2015; Stanovich, 1980). Taken together, the implication is that the ability to self-correct is a potentially powerful indicator of the degree of (re-) integration of multiple cognitive abilities used to reassess cue systems for accurate text processing.

Overall, both domain-specific and domain-general processes may support strategies, such as self-correction, to cope with reading difficulties. Reading skills predict students' acquisition of reading strategies. This link likely operates via a "bottom-up," text-driven mechanism, such that readers with greater decoding and word recognition may be better at acknowledging and self-correcting miscues. Moreover, EF is thought to contribute to reading skills and may, in turn, facilitate reading strategies (Afflerbach, Pearson, & Paris, 2008; see also Decker, Strait, Roberts, & Wright, 2017). Thus, EF likely plays an indirect role in self-correction via reading skills. On the other hand, self-correction is among the error-monitoring strategies, which are hypothesized as closely tied to EF (Borkowski, Chan, & Muthukrishna, 2000; Bowey, 1986; Deak, 2003; Oakhill et al., 2005). More efficient decoding and word recognition may perpetuate more EF resources in monitoring as well as fine-tuning students' subsequent reading performance (Borkowski et al., 2000; Smith, Borkowski, & Whitman, 2008). This thus suggests a competing hypothesis in that, potentially through a "top-down" mechanism, reading skills may have an indirect effect on reading strategies via EF (Borkowski et al., 2000; see also Decker, Strait, Roberts, & Wright, 2017). The extent to which one (reading skills versus EF) mediates the link between the other (EF versus reading skills, respectively) and reading strategies, such as self-correction, remains unknown.

Research questions

Prior investigations have not explicitly examined the relations between EF and miscues versus self-corrections. We aimed to address these current gaps in the literature. We hypothesized that reading difficulties, as indexed by more miscues, would be predicted by both poorer reading and language skills and worse EF. And, we hypothesized that greater probability of self-correcting a miscue [P(SC)] would be correlated with better reading and language abilities and better EF. Finally, we hypothesized that there are two possible competing mechanisms that readers operate on to self-correct. First, EF may contribute to students' P(SC) via reading skills, operating via a bottom-up mechanism. Second, EF may act as an additional, top-down mechanism beyond reading skills to predict P(SC).

Methods

Participants

This study was conducted in accordance with Vanderbilt University's Institutional Review Board guidelines. This sample was drawn from the first wave of a four-year longitudinal investigation of oral language and reading comprehension. Upon completion of first grade, 200 children were recruited from local schools as well as greater Nashville, Tennessee area (clinics, pediatricians' offices). First-grade students are exposed to strategies such as self-corrections to guide them in attaining sufficient reading performance. Therefore, this age range was thought to be an optimal time to capture whether self-corrections were related to EF.

Prior to enrollment, telephone screening was conducted to ensure that potential participants met inclusionary criteria. Children were excluded based on the following criteria: (1) known uncorrectable visual impairment; (2) treatment of any psychiatric disorder (other than Attention-Deficit/Hyperactivity Disorder (ADHD)) with psychotropic medications. Children with ADHD who were treated with medications other than stimulants were excluded; (3) history of known neurologic disorder (e.g., epilepsy, spina bifida, cerebral palsy, and traumatic brain injury); (4) documented hearing impairment greater than or equal to a 25 dB loss in either ear; (5) individuals known to have IQs below 80; (6) history or presence of a pervasive developmental disorder; and (7) if, during testing, parental responses from the Diagnostic Interview for Children and Adolescents-IV (DICA-IV; Reich, Leacock, & Shanfeld, 1997) indicated any severe psychiatric diagnoses, including major depression, bipolar disorders, and conduct disorder.

Parents provided written consent and children provided assent. Parents also completed the Hollingshead Four-Factor Index (Hollingshead, 1975) to estimate childhood socioeconomic status (SES). Compensation was received for participating in the study. In addition to these exclusion/inclusion criteria, children in this study were selected to have at least a basic level of word recognition and decoding ability, which we operationalized as a minimum standard score of 75 or above on the Basic Reading composite score of the Woodcock–Johnson Psychoeducational Battery. Children were also required to have a score equivalent to a standard score of 85 (out of 100) or above on the Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI). Of the recruited 200, 140 met the criteria for study inclusion. As 58 did not complete the Qualitative Reading Inventory, the final sample included 82 children with an age of 7.49 years (SD = 0.336). Forty-six (56%) participants were female; 50 (61%) were Caucasian, 27 (33%) were African-American; 4 (5%) were identified by their parents as more than one race; and 4 (5%) identified themselves as Hispanic/Latino.

Graduate-level research assistants assessed participants on reading and language skills in two sessions. All assessments were double-scored to ensure accuracy, and testing sessions were also audio-recorded to enable inter-rater assessment (Cohen's $\kappa > 0.43$).

Reading and language

Woodcock–Johnson Psychoeducational Battery (WJ-III; *Woodcock, McGrew, & Mather, 2001)*

Children read aloud single words (Word Identification) and non-words (Word Attack). Standardized scores based on participants' age from these subtests were used to determine the basic reading composite score (WJ-BR). Readers also completed the passage comprehension subtest (WJ-PC), estimating their understanding of written texts by matching items or supplying missing words to sentences and paragraphs of increasing complexity. The reliability coefficients for these subtests fall between 0.84 and 0.99 and concurrent validity with respect to other Woodcock–Johnson subtests between 0.43 and 0.82. The standard score for these subtests has M = 100, SD = 15.

Wechsler Abbreviated Scale of Intelligence (WASI; *Wechsler, 2011)*

Children completed the Vocabulary subtest of the WASI (WASI–VS). Children were asked to name visually presented items and to define words presented visually and orally. This subtest measured children's semantic knowledge and verbal comprehension. The reliability coefficient is reported as 0.91 and validity as 0.72 compared to the Wechsler Intelligence Scale for Children (Wechsler, 2011). The T-score for this subtest has M = 50, SD = 10.

Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, and Rashotte, 1999)

The Elision, Blending Words, and Sound Matching subtests were administered to determine the Phonological Awareness (CTOPP-PA) composite score. During the Elision subtest, children were asked to say a word and then repeat it a second time with a phoneme removed to create a new word. During the Blending Words subtest, children were asked to combine phoneme segments to create a word. During the Sound Matching subtest, children were asked to match words with the same initial or final speech sounds. CTOPP-PA estimated readers' ability to access the phonological structure of oral language. The Rapid Letter Naming and Rapid Digit Naming subtests were administered to determine the Rapid Naming (CTOPP-RN) composite score. During the Rapid Letter Naming subtest, children were asked to quickly produce the name of the serially presented letters. During the Rapid Digit Naming subtest, children were asked to quickly produce the name of the serially presented numbers. The CTOPP-RN targeted the readers' speed of articulation and verbal attention. The reliability coefficients for CTOPP-PA and CTOPP-RN fall between 0.88 and 0.96, whereas validity has been reported as within 0.51–0.71 in relation to WJ-III and Test of Word Reading Efficiency (Wagner et al., 1999). Standard scores for these composite indices have M = 100, SD = 15.

Clinical Evaluation of Language Fundamentals (CELF-IV; Semel, Wiig, and Secord, 2003)

Formulated Sentences (CELF-FS) and Recalling Sentences (CELF-RS) subtests were administered and measured readers' sentence-processing abilities: Whereas CELF-FS required the participant to generate semantically and grammatically sound sentences that include orally cued words or phrases, CELF-RS asked the participants to recall and repeat the sentences with varying length and syntactic complexity. The reliability coefficients for CELF-RS and CELF-RS fall between 0.86 and 0.94, and validity is above 0.70 when compared with CELF-III (Semel et al., 2003). Scaled scores for these subtests have M = 10, SD = 3.

Executive function

Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, and Kenworthy, 2013)

Parents answered 86 three-point questions (never, sometimes, and often) regarding their child's behavior. The questionnaire is composed of eight clinical EF sub-scales: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. Based on previous work on reading fluency, four EF components were analyzed: Shift (BRIEF-Shift), Working Memory (BRIEF-WM), Monitor (BRIEF-Monitor), and Inhibit (BRIEF-Inhibit) (e.g., Nathan & Stanovich, 1991; Perfetti et al., 1996; Pratt & Urbanowski, 2015; Shankweiler, 1999; Wolf & Katzir-Cohen, 2001). The BRIEF-Shift estimates a child's ability to flexibly transition between tasks. The BRIEF-Inhibit measures a child's impulse control. The BRIEF-WM assesses a child's ability to hold mental information for the purpose of completing a task. The BRIEF-Monitor determines a child's ability to assess his/her own performance. In contrast to other standardized assessments in this manuscript, higher scores on the BRIEF indicate worse EF, while lower scores signify better EF. The questionnaire has high interrater reliability correlation (0.82), item-total correlations, and Cronbach's α for internal consistency of 0.80–0.98; and validity falls between 0.57 and 0.82 when compared to the ADHD Rating Scale, Child Behavior Checklist, and DICA-IV (Achenbach, 1991; DuPaul, Power, Anastopoulos, & Reid, 1998; Mahone et al., 2002; Reich et al., 1997), and concurrent validity was between 0.72 and 0.84 (Gioia, Isquith, Guy, & Kenworthy, 2000). The standard scores have M = 50, SD = 10.

Reading fluency

Qualitative Reading Inventory (QRI; *Leslie & Caldwell, 2011)*

At each grade level, there are two narrative and two expository passages. Passage administration was counterbalanced across two lists in which participants were asked to read aloud one narrative and one expository text, with a possible combination of between 295 and 326 words for each list. The Harris–Jacobson readability levels fell between 1.5 and 1.8, and the Fountas and Pinnell grade-level ratings were either H or I. The QRI has reliability estimate >0.90 and validity of 0.85 (for first grade) for measures of miscues and comprehension with other tests of reading achievement and instructional levels (Leslie & Caldwell, 2011; Nilsson, 2013). All errors made during oral reading were considered as miscues (addition, mispronunciation, omission, reversal, word provided, and repetition). An unprompted correction following each miscue was a self-correction. Miscues and self-corrections were scored both while participants read aloud and after the administration using audio recordings. Since all participants made miscues (Table 1 and Supplementary Table 2), individuals who did not self-correct were assigned a zero score. All participants' performance was double-scored. Significantly more miscues ($t(81) = 7.636$; $p < 0.05$) and self-corrections ($t(81) = 4.155$; $p < 0.05$)

Table 1. Descriptive statistics across measures of reading, language, and executive functions for the whole sample ($n = 82$).

Variable	M	SD	Range
Demographics			
Age	7.49	0.336	6.75–8.17
Sex		56% Female; 44% Male	
Childhood SES	46.01	10.62	16.00–62.00
Reading Fluency			
Miscues	43.72	43.46	2.00–174.00
Self-Corrections	2.20	2.49	0.00–11.00
P(SC)	0.07	0.09	0.00–0.50
QRI-WCPM	65.93	30.82	10.62–150.59
Vocabulary			
WASI-VS	52.60	11.07	20.00–80.00
Comprehension			
WJ-PC	102.25	12.11	79.00–132.00
Basic Reading			
WJ-BR	106.15	10.04	83.00–131.00
Phonological Abilities			
CTOPP-PA	100.55	10.87	79.00–136.00
CTOPP-RN	99.61	9.84	70.00–124.00
Language Skills			
CELF-RS	9.82	3.15	3.00–16.00
CELF-FS	10.17	3.34	1.00–16.00
Executive Functions			
BRIEF-WM	54.30	14.71	35.00–86.00
BRIEF-Shift	48.01	12.13	37.00–91.00
BRIEF-Monitor	50.57	11.77	33.00–82.00
BRIEF-Inhibit	51.41	11.80	36.00–83.00

Childhood SES = childhood socioeconomic status, Hollingshead Four-Factor Index; *P*(SC) = probability of self-correcting miscues, log-transformed; QRI-WCPM = Qualitative Reading Inventory, Words Correctly Read per Minute; WASI–VS = Wechsler Abbreviated Scale for Intelligence, Vocabulary; WJ-PC = Woodc–Johnson, Passage Comprehension; WJ-BR = Woodcock–Johnson, Basic Reading; CTOPP-PA = Comprehensive Test of Phonological Processing, Phonological Awareness; CTOPP-RN = Comprehensive Test of Phonological Processing, Rapid Naming; CELF-RS = Clinical Evaluation of Language Fundamentals, Recalling Sentences; CELF-FS = Clinical Evaluation of Language Fundamentals, Formulating Sentences; BRIEF-Shift = Behavior Rating Inventory of Executive Function, Shift; BRIEF-WM = Behavior Rating Inventory of Executive Function, Working Memory; BRIEF-Monitor = Behavior Rating Inventory of Executive Function, Monitor; BRIEF-Inhibit = Behavior Rating Inventory of Executive Function, Inhibit.

were found for expository versus narrative passages. Since the examination of the genre effect is beyond the scope of the current study, data were collapsed across passages.

Statistical analyses

Of the 82 participants, 2% were missing BRIEF scores and 12% were missing CTOPP scores. Markov-Chain Monte-Carlo algorithms were used to impute missing values for hypothesized predictors (m = 5; SPSS Version 25) (Rubin, 1996, 1976, Schafer & Graham, 2002). Correlations were run to confirm the relation between reading, language, and EF abilities.

To investigate our first question of the relation between miscues (of any type, but not including self-corrections) and reading, language, and EF abilities, we employed hierarchical regressions using the entire sample. After including demographic factors (age, sex, SES) [Step 1], bottom-up code-/print-related skills (phonological processes [Step 2] and basic reading [Step 3]) were entered as individual steps before top-down lexical- and sentence-level processes (vocabulary [Step 4] and language skills [Step 5]). EF was entered last [Step 6] to isolate its unique contribution.

Self-correction scaling

We scaled each participant's number of self-corrections by their total number of miscues (both uncorrected and corrected), thus creating a probability of self-correcting a miscue [P(SC)] (see Clay, 1969; Pflaum & Bryan, 1980).

$$\mathrm{P(SC)} = \frac{\text{self} - \text{corrections}}{\text{uncorrected miscues} + \text{corrected miscues}}$$

Not all miscues may be self-corrected. Thus, analyses were conducted for both the P(SC) for all types of miscues and the P(SC) for only those that could be self-corrected (omissions, substitutions, additions, mispronunciations, and word reversals). Notably, no significant difference in P(SC) was found for expository versus narrative passages ($t(81) = 1.256$; $p = 0.213$).

To investigate our second question of the relation between P(SC) and reading, language, and EF abilities, only readers who had made at least one self-correction (n= 50) were analyzed. In focusing on readers who made *and* self-corrected a miscue, the study capitalized on the phenomenon of self-correction. We first examined correlations in this restricted sample between reading, language, and EF abilities and P(SC), as well as all miscues (of any type), determining their equivalency with the whole sample. Next, we employed hierarchical regressions to capture the unique variance that EF contributed to predicting P(SC), beyond reading- and language-supporting factors and demographic factors. Analyses were conducted with a composite measure of EF (see *Preliminary Analyses*), as well as with individual BRIEF sub-scales (Inhibit, Shift, Working Memory, and Monitor) in order to understand whether specific EF components were related to miscues and P(SC), versus global EF more generally.

To address our third question, we built a series of mediation analyses to evaluate the extent to which reading skills versus EF mediates the links between EF versus reading skills, respectively, and P(SC).

Results

Preliminary analyses

Prior to conducting any analyses, several steps were taken to address any skewness in the data and to reduce the BRIEF subscales into a composite variable. P(SC) was positively skewed (Shapiro–Wilk = 0.743, $p < 0.001$; skewness = 2.19, kurtosis = 5.93) and was log-transformed to result in a normal distribution (Shapiro–Wilk = 0.990, $p > 0.05$; skewness = −0.61, kurtosis = −0.088) and included in the analyses. All other variables were normally distributed. A composite score for the four BRIEF subscales (BRIEF-Shift, BRIEF-WM, BRIEF-Monitor, and BRIEF-Inhibit) was derived with principal component analysis, using varimax rotation to maximize their variance loadings. The first component captured 74% of the total variance and was used as the BRIEF's principal component (BRIEF-PC). All four BRIEF subscales loaded highly into BRIEF-PC (Pearson's $r > 0.80$). Overall descriptive statistics including P(SC) (before log-transformed) and BRIEF-PC can be found in Table 1 for the whole sample (N = 82) and Supplementary Table 1 for the restricted sample (n = 50). Descriptive statistics for types of miscues can be found in Supplementary Table 2. Initial correlational analyses, using standardized scores, confirmed replication of previously reported relations between reading, language, and EF abilities and demographic factors (Table 2). To confirm the parallel findings of the larger group, correlational analyses were also run in the restricted sample (n = 50) to examine the relation between reading, language, EF, miscues, and P(SC) (Table 3). As expected, across the full sample (N = 82) and restricted sample (n = 50), all reading, language, and EF measures were significantly correlated with miscues ($p < 0.01$). Except for the WASI–VS, BRIEF-Monitor, and BRIEF-Inhibit, P(SC) in the restricted sample (n = 50) was also correlated with reading, language, and EF measures. While poorer EF was correlated with more miscues, better EF correlated with higher P(SC). Additionally, individuals who did not make any self-corrections (n = 32) produced less miscues and had better reading, language, and EF skills, as compared to those who made at least one self-correction (Supplementary Table 1).

Reading, language, and executive abilities predicting miscues

Hierarchical regressions were employed to evaluate the contributions of reading and language processes to miscues (N = 82; Tables 4 and 5). The overall model was significant, $F(10, 72) = 22.02$, $p < 0.05$, and accounted for 73% of miscue variance. After accounting for demographic factors, phonological processes and basic reading were negatively related to miscues and significantly contributed 13–26% of unique variance. Language abilities were also negatively related to miscues and accounted for an additional 9% of the variance. In other words, children with poorer phonological and word-reading skills who also struggle to formulate semantically and grammatically correct sentences are likely to make more errors while reading aloud.

While the composite EF score (BRIEF-PC) was significantly correlated with miscues (Table 2), this was not the case after controlling for reading and language abilities, as well as demographic factors. Additional analyses were conducted to evaluate whether there was a relation between miscues and specific EF components, as hypothesized, in individual steps.

When evaluating the EF components individually, only task-shifting (BRIEF-Shift) was positively related to miscues, significantly contributing 1% of unique variance (Table 4). When replicating these steps for the subset of readers who made at least one self-correction (n = 50), the relation between miscues and BRIEF-Shift remained significant, accounting for 3% of unique variance (Table 5). Thus, children who displayed more difficulty with task-shifting ability (higher BRIEF score) were likely to make more errors while reading aloud. The predictive effect of BRIEF-WM was also significant (Table 5).

Relation between EF and P(SC)

Hierarchical regressions were employed to examine the unique contributions of reading, language, and EF abilities in predicting the probability of self-correcting a miscue [P(SC)]. Mediation analyses were run to address our final question, which was to determine whether basic reading versus EF mediated the relation between P(SC) and EF and reading, respectively (Table 6 and Figure 1). Both hierarchical regression and mediation analyses were conducted with the subset of readers who made at least one self-correction (n = 50).

The overall hierarchical regression model that included the first five steps of the model was significant, $F(10, 40) = 3.464$, $p < 0.05$, and accounted for 45% of the variance in P(SC) of any types

Table 2. Correlations among measures of reading, language, and executive functions for the whole sample (n = 82).

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	QRI-Miscues	-																
2	QRI-WCPM	−0.67**	-															
3	WJ-PC	−0.65**	0.69**	-														
4	WJ-BR	−0.65**	0.70**	0.83**	-													
5	WASI-VS	−0.41**	0.40**	0.47**	0.48**	-												
6	CTOPP-PA	−0.45**	0.46**	0.60**	0.65**	0.46**	-											
7	CTOPP-RN	−0.27**	0.40**	0.47**	0.38**	0.10	0.32**	-										
8	CELF-RS	−0.56**	0.50**	0.67**	0.56**	0.58**	0.51**	0.23*	-									
9	CELF-FS	−0.74**	0.59**	0.74**	0.69**	0.62**	0.57**	0.17	0.72**	-								
10	BRIEF-WM	0.36**	−0.44**	−0.46**	−0.29**	−0.30**	−0.26*	−0.34**	−0.35**	−0.31**	-							
11	BRIEF-Shift	0.36**	−0.32**	−0.42**	−0.30**	−0.18	−0.23*	−0.28*	−0.29**	−0.28**	0.63**	-						
12	BRIEF-Monitor	0.25**	−0.29**	−0.46**	−0.24*	−0.16	−0.25*	−0.44**	−0.41**	−0.32**	0.66**	0.65**	-					
13	BRIEF-Inhibit	0.33**	−0.30**	−0.36**	−0.19	−0.17	−0.15	−0.28*	−0.41**	−0.38**	0.49**	0.66**	0.74**	-				
14	BRIEF-PC	0.38**	−0.39**	−0.42**	−0.48**	−0.29*	−0.23*	−0.26*	−0.40**	−0.42**	0.81**	0.86**	0.89**	0.85**	-			
15	Age	−0.27*	0.03	−0.24*	−0.26*	0.09	−0.13	−0.11	0.10	0.03	−0.03	−0.01	0.04	−0.08	−0.09	-		
16	Sex	0.00	−0.03	−0.11	−0.07	−0.09	−0.15	−0.07	−0.02	−0.02	0.12	0.03	0.06	0.04	0.04	0.19	-	
17	Childhood SES	−0.48**	0.42**	0.49**	0.47**	0.23*	0.44**	0.13	0.49**	0.49**	−0.22	−0.26*	−0.17	−0.29**	−0.24	0.10	0.02	-

*p < 0.05. **p < 0.01. Note: Sex is coded as a dummy variable, where female = 0 and male = 1.

Table 3. Correlations between miscues and *P(SC)* and readers' reading, language, and executive abilities for a subset of those who self-corrected (n = 50).

Variable		Miscues	P(SC)
1	QRI-WCPM	−0.704**	0.636**
2	WJ-PC	−0.700**	0.459**
3	WJ-BR	−0.678**	0.469**
4	WASI-VS	−0.421**	0.241†
5	CTOPP-PA	−0.467**	0.276*
6	CTOPP-RN	−0.255†	0.317*
7	CELF-RS	−0.566**	0.311*
8	CELF-FS	−0.748**	0.368**
9	BRIEF-WM	0.301**	−0.445**
10	BRIEF-Shift	0.423**	−0.454**
11	BRIEF-Monitor	0.167	−0.127
12	BRIEF-Inhibit	0.301*	−0.201
13	BRIEF-PC	0.349*	−0.357*
14	Age	−0.291*	0.212
15	Sex	0.066	−0.238†
16	Childhood SES	−0.410**	0.181

†$p < 0.10$; *$p < 0.05$. **$p < 0.01$.

Table 4. Summary of hierarchical regression analyses predicting miscues from reading, language, and executive skills for the whole sample (n = 82).

	Miscues				
Regression and Steps	*β*	R^2	ΔR^2	*F*	ΔF
Step 1 + Demographic Factors		0.258	0.258	9.035**	9.035**
Age	−0.237				
Sex	0.068				
Childhood SES	−0.430				
Step 2 + Phonological Processes		0.391	0.133	9.756**	8.301**
CTOPP-PA	−0.315**				
CTOPP-RN	−0.185†				
Step 3 + Basic Reading		0.648	0.257	22.98**	54.64**
WJ-BR	−0.743**				
Step 4 + Vocabulary		0.648	0.000	19.44**	0.014
WASI-VS	−0.010				
Step 5 + Language Skills		0.734	0.086	22.02**	11.59**
CELF-RS	0.043				
CELF-FS	−0.501**				
Step 6 + Executive Functioning		0.739	0.005	20.09**	1.462
BRIEF-PC	0.085				
Step 6 + Executive Components					
a. BRIEF-WM	0.088	0.740	0.006	20.18**	1.697
b. BRIEF-Shift	0.116*	0.745	0.012	20.78**	3.287*
c. BRIEF-Monitor	0.031	0.734	0.001	19.61**	0.179
d. BRIEF-Inhibit	0.037	0.734	0.001	19.64**	0.254

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$.

of miscues. Only basic reading positively predicted *P*(SC), significantly contributing 18% of unique variance. EF (BRIEF-PC) significantly explained an additional 5% of unique variance in the overall model (R^2 = 0.503), $F(11, 39) = 3.715$, $p < 0.05$.

Additional analyses were conducted to evaluate whether there was a relation between *P*(SC) and specific EF components, as hypothesized, in individual steps. The results revealed that, after controlling for demographic factors and reading and language abilities, working memory (BRIEF-WM) and task-shifting (BRIEF-Shift) significantly negatively predicted *P*(SC), accounting for an additional 9% and 7%, respectively, of the total variance. Neither BRIEF-Monitor nor BRIEF-Inhibit made any significant contribution to *P*(SC) variance.

Table 5. Summary of hierarchical regression analyses predicting miscues from reading, language, and executive skills for readers who self-corrected ($n = 50$).

	Miscues				
Regression and Steps	β	R^2	ΔR^2	F	ΔF
Step 1 + Demographic Factors		0.218	0.218	4.375**	4.375**
Age	−0.190				
Sex	0.127				
Childhood SES	−0.389				
Step 2 + Phonological Processes		0.435	0.216	6.918**	8.608**
CTOPP-PA	−0.389**				
CTOPP-RN	−0.269*				
Step 3 + Basic Reading		0.716	0.281	18.46**	43.49**
WJ-BR	−0.720**				
Step 4 + Vocabulary		0.717	0.001	15.54**	0.152
WASI-VS	−0.039				
Step 5 + Language Skills		0.733	0.016	12.49**	1.230
CELF-RS	0.030				
CELF-FS	−0.239				
Step 6 + Executive Functioning		0.766	0.033	13.08**	5.656*
BRIEF-PC	0.211*				
Step 6 + Executive Components					
a. BRIEF-WM	0.172*	0.758	0.025	12.53**	4.173*
b. BRIEF-Shift	0.194*	0.764	0.031	12.92**	5.234*
c. BRIEF-Monitor	0.155†	0.750	0.017	12.00**	2.761†
d. BRIEF-Inhibit	0.184†	0.755	0.022	12.31**	3.592†

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$.

Table 6. Summary of hierarchical regression analyses predicting *P(SC)* from reading, language, and executive skills for readers who self-corrected ($n = 50$).

	P(SC)				
Regression and Steps	β	R^2	ΔR^2	F	ΔF
Step 1 + Demographic Factors		0.152	0.152	2.806†	2.806†
Age	0.254†				
Sex	−0.298*				
Childhood SES	0.144				
Step 2 + Phonological Processes		0.273	0.122	3.387*	3.764*
CTOPP-PA	0.228				
CTOPP-RN	0.259†				
Step 3 + Basic Reading		0.451	0.178	6.032**	14.26**
WJ-BR	0.573**				
Step 4 + Vocabulary		0.452	0.000	5.060**	0.028
WASI-VS	0.023				
Step 5 + Language Skills		0.452	0.001	3.764**	0.028
CELF-RS	−0.040				
CELF-FS	0.011				
Step 6 + Executive Functioning		0.503	0.051	4.048**	4.071*
BRIEF-PC	−0.260*				
Step 6 + Executive Components					
a. BRIEF-WM	−0.322**	0.542	0.089	4.725**	7.778**
b. BRIEF-Shift	−0.301*	0.527	0.074	4.451**	6.278*
c. BRIEF-Monitor	−0.093	0.323	0.006	3.389**	0.460
d. BRIEF-Inhibit	−0.125	0.463	0.010	3.444**	0.760

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$.

Regressions models were also replicated for the P(SC) for miscues that could be self-corrected (see *Methods* & Supplementary Table 2). The predictive effects of BRIEF-WM and BRIEF-Shift remained significant (Supplementary Table 3). Thus, readers who were more likely to self-correct their miscues had better working memory and/or task-shifting (lower BRIEF scores).

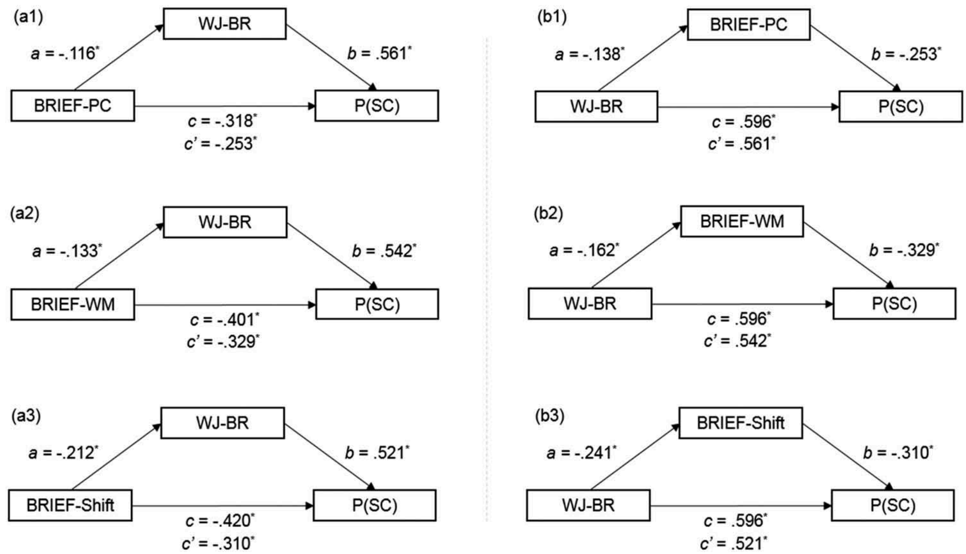

Figure 1. Path models for mediation analyses with WJ-BR mediating the relations between (a1) BRIEF-PC, (a2) BRIEF-WM, and (a3) BRIEF-shift and *P*(SC); and with (b1) BRIEF-PC, (b2) BRIEF-WM, and (b3) BRIEF-shift mediating the relations between WJ-BR and *P*(SC).

To test the mechanisms by which reading skills versus EF explained students' ability to self-correct, we built two series of mediation models. First, we investigated if basic reading skills (WJ-BR) mediated the link between EF and *P*(SC). As expected, both basic reading skills (*path b*) and EF (*path c*) significantly predicted *P*(SC), after controlling for demographic factors (Figure 1 and Supplementary Table 4, *a1-3*). The Sobel test revealed a significant partial mediation (Preacher & Hayes, 2004), which indicated the presence of both direct and indirect effects. Second, we examined if, alternatively, EF played a role in the relation between basic reading skills (WJ-BR) and *P*(SC). Both EF (*path b*) and basic reading skills (*path c*) significantly explained differences in *P*(SC) (Figure 1 and Supplementary Table 4, *b1-3*). The Sobel test also revealed a significant partial mediation. These results thus suggest two possible mechanisms underlying self-correction: basic reading skills *and* EF.

Discussion

Reading fluency has long been recognized as predictive of reading competence. The overarching aim of the current study was to evaluate the relation between two components of ORF-*P* – miscues and self-corrections – and EF beyond reading and language abilities. Results from our study indicate the potentially interactive-compensatory involvement of EF in resolving reading difficulties via self-corrections. While self-corrections may emerge as a byproduct of efficient reading- and language-related abilities, EF may also serve as a scaffold for readers' awareness of and ability to resolve oral reading errors.

Do poorer reading- and language-related abilities and ineffective EF predict reading difficulties?

We hypothesized that readers with poorer reading, language, and EF abilities would produce more miscues. Poorer basic reading predicted more miscues, which is consistent in that word-level processes are critical to ORF-P (Hudson et al., 2008). Readers also rely on oral reading abilities while reading aloud (Muter, Hulme, Snowling, & Stevenson, 2004; Shankweiler et al., 1995). In support of this, we found that measures of oral language significantly explained miscue variance. Particularly relevant to our study, difficulty with ORF-P has been hypothesized to be related to individual differences in EF (Berninger et al., 2001; Meyer & Felton, 1999; Miller et al., 2014; Spencer et al., 2018; Wolf & Katzir-Cohen, 2001). We found that task-shifting significantly accounted for 1% of unique miscue variance. Although the additional miscue variance is small after taking into account multiple reading and language abilities, our findings support the link between less effective EF and reading difficulties.

While previous evidence clearly supports the role of reading- and language-related abilities, one might ask why less effective EF is related to more miscues. One explanation for our results is that readers' attention may be constrained by contextual facilitation (Biemiller, 1970; Bowey, 1985; Stanovich, 1980). The remaining cognitive resources are likely not dispensed adequately among reading- and language-supporting domains (Nation & Snowling, 1998; Perfetti, 1985; Stanovich, 1980; Torgesen & Hudson, 2006). Biemiller's studies (1970, 1979), also in a cohort of first-graders, reported that oral reading errors likely emerged from word- and passage-level (contextual) difficulties (see also Chinn et al., 1993). In his "interactive-compensatory" model, Stanovich (1980) suggested that miscues might also indicate deficits in top-down (working memory and task-shifting) processes. That is, EF may be involved in efficient communication among reading- and language-supporting domains for fluent reading.

Is self-correction, which allows readers to resolve miscues, related to effective recruitment of reading- and language-related skills *and* EF?

We hypothesized that self-corrections would be supported by reading- and language-related skills, as well as EF. Previous reports hypothesized that EF might play a role in readers' ability to self-correct (Clay, 1969; D'Angelo, 1981; McGee et al., 2015), yet none have explicitly examined this assertion. Clay (1969) suggested that self-correction was an immediate response to textual and contextual dissonance, involving an awareness of "what makes sense" versus "what is said." This event of error-detection was followed by a sequential coordination of shifting attention toward and visually inspecting such discrepancies. McGee et al. (2015), extending Clay's findings (1969), tied their findings on miscues and self-corrections together with EF, speculating that self-corrections emerged as a strategy to resolve miscues (see Cartwright, 2012; Fuchs et al., 2001). We argue that, beyond reading- and language-related abilities, readers also recruit EF to self-correct. Here, we considered not only if EF played a role but also which specific BRIEF subscales of EF might support self-corrections while reading aloud.

To evaluate readers' handle on miscues, we focused on those who self-corrected at least once. Better basic reading significantly explained higher P(SC). Our sample of recent first-grade graduates has likely received some formal instruction on word-reading and self-correction strategies. Basic reading likely consumed the possible P(SC) variance partially explained by oral language. Readers with greater working memory and task-shifting exhibited higher P(SC). While BRIEF-Shift significantly predicted P(SC), individuals who did (versus did not) self-correct did not differ in BRIEF-Shift, suggesting its potentially unique role in self-corrections. Regardless, our results indicate that word-level skills and EF may serve as a prerequisite for readers' handle on miscues. According to Stanovich's "interactive-compensatory" theory (1980), top-down processes (EF) may be recruited to buffer reading difficulties, perhaps strategically through self-corrections.

Self-corrections may tap various EF components. Readers with greater working memory likely detect more miscues (Pearlmutter & MacDonald, 1995). Evan after having detected miscues, readers' cognitive resources are already divided among reading- and language-supporting skills. Task-shifting likely underlies readers' ability to (re-)allocate their attention to resolve the detected miscues (Cartwright, Marshall, Huemer, & Payne, 2019; Deak, 2003; Goral et al., 2011). While the examination of readers' EF in relation to specific types of miscues is beyond the scope of this study, different types have been speculated to tap different EF components (e.g., Daneman, 1991; De Beni, Palladino, Pazzaglia, & Cornodli, 1998; Denckla & Cutting, 1999; Engelhardt et al., 2013; Mann, Liberman, & Shankweiler, 1980). In our results, when focusing on only the miscues that could be self-corrected, the unique contributions of working memory and task-shifting to *P*(SC) remained significant. Future studies may consider extending this set of findings by examining the specific cognitive characteristics of different self-corrected miscues. Nonetheless, EF is arguably recruited as a potentially interactive-compensatory player in reading strategies.

Does basic reading mediate the link between EF and P(SC), and does EF mediate the relation between basic reading and P(SC)?

Finally, we investigated if EF provided an additional mechanism by which reading skills explained students' ability to self-correct. Reading skills are suggested to serve as the precursor for students acquiring reading strategies, such as self-correction. We found that EF contributed to self-correcting a miscue also via of basic reading skills. Alternatively, self-correction indicates students' efforts at error monitoring, which is directly associated with EF (e.g., Bowey, 1986; Oakhill et al., 2005; see also Garavan, Ross, Murphy, Roche, & Stein, 2002). Yet, even when a miscue is detected via EF, the ability to self-correct is also related to the specific skills (decoding and word recognition) that students draw upon (Jenkins, Larson, & Fleisher, 1983; Kolic-Vehovec, 2002). Our results revealed that EF significantly mediated the relation between basic reading skills and self-correcting a miscue. Yet, when considering the effect sizes between the two models, the indirect effect of EF on reading strategies via reading skills appears to be greater than that of reading skills via EF. This suggests that reading skills may play a more central role than EF in reading strategies. Nonetheless, our findings implicate two possible mechanisms that facilitate self-correcting miscues.

The contributions of domain-specific and domain-general skills are particularly important in the context of remediation. Most interventions typically focus on improving domain-specific abilities, targeting reading outcomes such as comprehension and fluency (Snowling & Hulme, 2014; Stevens, Walker, & Vaugh, 2017; Wolf & Katzir-Cohen, 2001). Less have considered remediating reading strategies (e.g., self-correction), especially while taking into account domain-general skills such as EF. For example, children with dyslexia who underwent working memory training improved significantly on their error-monitoring ability as well as overall ORF (Horowitz-Kraus & Breznitz, 2009). These gains were also observed when a reading intervention was administered in another study (Horowitz-Kraus & Breznitz, 2014). In piloting an intervention program that targets multiple sources of reading difficulties, including literacy (decoding and vocabulary), cognition (memory), and emotionality, recent studies posit that all of these components play a role in reading improvement ("OR" Intervention Program; Shaul et al., 2016). What remains unanswered is how to fully imbed EF into interventions for reading skills and strategies (Peng & Fuchs, 2017).

Limitations and future directions

While the current study contributes to the growing literature on the relation between reading, language, and EF, there are also limitations. First, the parent BRIEF rating scale was used to capture EF. Behavioral rating scales, such as the BRIEF, capture a more global coverage of daily goal-directed EF, which can be observed by the child's parents (i.e., "real-world" construct of EF; Bodnar, Prahme, Cutting, Denckla, & Mahone, 2007; Denckla, 2002). Yet, performance-based measures capture more fine-grained dimensions of EF by targeting specific cognitive processes (e.g., inhibition; Toplak, West, & Stanovich, 2012). The current study did not find a significant relation between self-corrections and inhibition, despite its strong theoretical support (e.g., Altemeier et al., 2008; Chiappe et al., 2000; Savage, Cornish, Manly, & Hollis, 2006). While the parent-rating BRIEF arguably taps the broader and more clinical construct of EF, inhibition might not have been sufficiently specified using this approach (Bodnar et al., 2007; Mcauley, Chen, Goos, Schachar, & Crosbie, 2010), especially in relation to reading (Mahone et al., 2002). Future studies may consider combining behavioral rating scales with performance-based EF measures, capturing both ecological and cognitive validity and sensitivity of participants' EF profile. Second, participants were administered with grade-level passages using the QRI in a limited sample size. Given that students' reading ability may vary widely at the end of first grade, reading passages that are matched on individual reading level is likely more appropriate, especially in terms of miscues and self-corrections. Future studies may consider further unpacking students' *P*(SC) using this text-leveling approach (e.g., Compton, Appleton, & Hosp, 2004), as well as in the larger sample of readers to enable more sophisticated statistical strategies. Third, the current study collapsed students' miscues and self-corrections across both genres, narrative and expository. Future studies may consider examining the relative contributions of text features and characteristics to students' reading strategies. Finally, there are two possible, competing mechanisms by which EF explains *P*(SC) byway of reading skills versus reading skills is related to *P*(SC) via EF (Borkowski et al., 2000). Future studies may consider testing these two competing hypotheses further to hone in on the role of EF in reading strategies.

Conclusion

This is the first study to capitalize on the potentially interactive-compensatory role of EF in two components of ORF-P, miscues and self-corrections, beyond reading and language abilities. Our results are largely consistent with prior literature in supporting that reading, language, and executive skills underlie ORF-P. Reading difficulties, as indexed by miscues, may be compensated if readers are able to self-correct dissonance by relying on top-down, domain-general cognitive abilities such as EF (Borkowski et al., 2000; Stanovich, 1980). Understanding the mechanisms underlying reading difficulties and strategies in relation to EF may help tailor remediation for struggling readers.

Disclosure statement

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