Resubmitting to ERIC to acknowledge funding.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305F100013 to The University of Texas at Austin as part of the Reading for Understanding Research Initiative. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Scientific Studies of Reading

ISSN: 1088-8438 (Print) 1532-799X (Online) Journal homepage: www.tandfonline.com/journals/hssr20

The Contribution of Attentional Control and Working Memory to Reading Comprehension and Decoding

C. Nikki Arrington, Paulina A. Kulesz, David J. Francis, Jack M. Fletcher & Marcia A. Barnes

Scientific Studies of Reading, 18:325–346, 2014

ISSN: 1088-8438 print/1532-799X online
DOI: 10.1080/10888438.2014.902461

Routledge
Taylor & Francis Group

The Contribution of Attentional Control and Working Memory to Reading Comprehension and Decoding

C. Nikki Arrington, Paulina A. Kulesz, David J. Francis, and Jack M. Fletcher
University of Houston

Marcia A. Barnes
University of Texas at Austin

Little is known about how specific components of working memory, namely, attentional processes including response inhibition, sustained attention, and cognitive inhibition, are related to reading decoding and comprehension. The current study evaluated the relations of reading comprehension, decoding, working memory, and attentional control in 1,134 adolescent students. Path analyses were used to assess the direct and indirect effects of working memory and aspects of attentional control on reading comprehension and decoding. There were significant direct effects of working memory, sustained attention, and cognitive inhibition on reading comprehension, but not decoding. There was a significant direct effect of working memory and response inhibition on decoding, but not comprehension. These results suggest that different aspects of attentional control are important for decoding versus comprehension.

Proficient reading requires the successful utilization and coordination of a number of cognitive processes and sources of knowledge. These include word-level skills (e.g., phonological decoding and vocabulary knowledge), text-level skills (e.g., inference making to maintain causal coherence; Cain, Oakhill, & Bryant, 2004), and general cognitive processes (e.g., working memory; Rapp, van den Broek, McMaster, Kendeou, & Espin, 2007). Together, the lower level processes associated with decoding, the higher level language and discourse processes associated with comprehension, and domain general cognitive abilities such as working memory contribute to the development of a coherent representation of the text. Although word recognition skills are necessary for reading comprehension, they are not sufficient. Decoding and reading comprehension skills have some overlap in cognitive correlates, but also some distinct cognitive correlates that may vary across development (Cain et al., 2004; Catts, Adlof, & Weismer, 2006; Gough & Tunmer, 1986; Hoover & Gough, 1990; Oakhill & Cain, 2012; Oakhill, Cain, & Bryant, 2003). The focus of the current study was to more closely investigate the contribution of several domain general cognitive processes, including working memory, inhibitory processes, and attention, to reading decoding and reading comprehension, in adolescent students varying in age and reading levels.

Correspondence should be sent to C. Nikki Arrington, Department of Psychology, University of Houston, Houston, TX 77004. E-mail: cnarring@central.uh.edu

WORKING MEMORY

Working memory is a temporary storage and processing system that is necessary for a range of cognitive tasks (Baddeley, 1986; Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Oakhill, 1993). In reading, working memory is involved with both single word decoding (Christopher et al., 2012; Swanson, Howard, & Saez, 2006; Swanson, Zheng, & Jerman, 2009) and comprehension of longer texts (Christopher et al., 2012; Daneman & Merikle, 1996; De Beni & Palladino, 2000; Sesma, Mahone, Levine, Eason, & Cutting, 2009; Swanson et al., 2006).

In decoding, working memory operates to access and monitor speech-based information (Swanson et al., 2009). Working memory is also necessary for the storage and retrieval of multi-level text necessary for reading comprehension (Swanson, 1999). Longitudinally, early working memory ability has been shown to uniquely predict the development of reading comprehension skills (Cain et al., 2004; Seigneuric & Ehrlich, 2005; Swanson, 2011). Both poor decoders and those students with poor reading comprehension not associated with poor word reading skills (i.e., poor comprehenders) show evidence of deficits in working memory. However, working memory may operate differently in reading decoding and reading comprehension (Catts et al., 2006; Christopher et al., 2012; Cutting, Materek, Cole, Levine, & Mahone, 2009; Locascio, Mahone, Eason, & Cutting, 2010; Palladino & Ferrari, 2013; Swanson et al., 2006). In particular, skills related to the central executive component of working memory may be differentially involved in these reading components.

The central executive is one of three functional components in Baddeley's multiple-component model of working memory that act together for the production of the moment-by-moment monitoring, processing, and maintenance necessary for information processing associated with proficient reading (Baddeley & Hitch, 1974; Baddeley & Logie, 1999). The phonological loop and visuospatial sketchpad, responsible for the processing and maintenance of verbally encoded and visual/spatial information, respectively, act as slave systems to the central executive. A key function of the central executive is the allocation of attentional resources (Barrett, Tugade, & Engle, 2004). Individual differences in working memory are significantly impacted by individual differences in the ability to control attention. These attentional control processes are crucial for cognitive processes supporting language and reading comprehension (Gathercole & Baddeley, 1993). Because working memory refers to a domain-general skill that is composed of multiple cognitive processes, and the longitudinal predictors and cognitive correlates of reading decoding and comprehension are partly dissociable (Oakhill et al., 2003; Sesma et al., 2009), one important question is whether different aspects of working memory, such as attentional control, are related to reading decoding versus reading comprehension. Although it has been established that suppression difficulties, due to poor attention control, result in problems with the regulation of contents of working memory that can impede reading, the nature of these deficits and their relation to decoding versus reading comprehension is not well understood (De Beni & Palladino, 2000; Pimpterton & Nation, 2010).

ATTENTIONAL CONTROL

Also referred to as inhibitory or interference control, attentional control is associated with the ability to inhibit or suppress interfering, irrelevant, or prepotent responses and to initiate those processes that are more relevant while maintaining attention on task-relevant information (Conners, 2009; Gathercole & Baddeley, 1993; Nigg, 2000). Attentional control is not a singular, generalized mechanism but instead exists as a "family of functions" (Cain, 2006; Wilson & Kipp, 1998). Response inhibition, sustained attention, and cognitive inhibition are three potentially independent functions of attentional control, but their separable relations, particularly as they relate to reading comprehension versus decoding, have not been determined. The smooth coordination of these processes is hypothesized to positively impact reading proficiency and promote a coherent understanding of the text.

Response Inhibition

Behavioral inhibition, commonly referred to as response inhibition, is the deliberate or effortful, controlled suppression of dominant, automatic, or prepotent responses to external stimuli (Logan & Cowan, 1984; Wilson & Kipp, 1998). This process results in the sudden and complete stopping of an individual's planned or ongoing actions at the point at which these actions become inappropriate, as a result of a change in the immediate environment (Williams, Ponesses, Schachar, Logan, & Tannock, 1999). Logan and Cowan's (1984) "horserace" model indicates that response inhibition is the result of an internal race between excitatory go processes and inhibitory stop processes, in response to an external stimulus. Successful inhibition occurs when the controlled stop process responds to the stimulus before the prepotent go process is completed.

Deficits in both response inhibition and working memory are evident in students with poor decoding skills, particularly in children with comorbid reading difficulties and attention deficits (de Jong et al., 2009; Purvis & Tannock, 2000). On go–no go tasks such as the Stop Signal Paradigm, children with word reading difficulties with or without an accompanying attention disorder have been shown to have longer stop signal reaction times (SSRT), as compared to typically developing readers, suggesting reduced response inhibition skills in these children (de Jong et al., 2009; Purvis & Tannock, 2000). Students with poor word reading skills also perform significantly poorer on traditional measures of response inhibition, such as the Stroop task (van der Schoot, Licht, Horsley, & Sergeant, 2000) and the Conflicting Motor Response task (Locascio et al., 2010). For example, after controlling for socioeconomic status and attention deficits, students with poor word reading skills showed significantly poorer performance on measures of response inhibition and working memory, as compared to typical controls (Locascio et al., 2010). In contrast, a recent study that took a latent variable approach showed that in 8- to 16-year-olds, response inhibition was not uniquely predictive of word reading, when also accounting for working memory, processing speed, and naming speed (Christopher et al., 2012). These conflicting findings suggest that the relation between response inhibition, working memory, and decoding is not well understood.

On the other hand, studies examining the relation between response inhibition and reading comprehension have not found a significant relation between the two in either typically developing children or children with reading comprehension difficulties (Alloway, Elliot, & Place, 2010; Christopher et al., 2012; Locascio et al., 2010). For example, Locasio et al. (2010) found that response inhibition did not differ in children with specific difficulties in comprehension compared to typically developing children. Christopher et al. (2012) found that response inhibition was not uniquely predictive of reading comprehension. In sum, relations between response inhibition and word reading are somewhat ambiguous, though there seems to be no evidence for an association of response inhibition with reading comprehension.

Sustained Attention

Sustained attention provides for the ability to maintain attention and focus on task-relevant goals over an extended period (Astle & Scerif, 2011). That being said, inattention does not present with a complete lack of attention but rather an inconsistent, on-and-off pattern in which attention is not consistently directed toward the intended task (Aaron, Joshi, Palmer, Smith, & Kirby, 2002; Smallwood, Fishman, & Schooler, 2007). Adequate reading requires sustained attention in order to maintain an active representation of the text being read. Measures of sustained attention are significantly correlated with measures of both single word decoding and reading comprehension (Savage, Cornish, Manly, & Hollis, 2006; Sesma et al., 2009). Silva-Pereyra et al. (2010) found that poor readers, as defined by having reduced word reading or reading comprehension skills, performed significantly poorer on a measure of sustained attention, as compared to those individuals with typically developing reading ability. Sustained attention has also been shown to predict reading decoding in elementary school students, independent of phonological skills (Bosse & Valdois, 2009).

Poor sustained attention has been shown to negatively impact reading comprehension. For example, students with more frequent periods of inattention during reading also performed poorer on a measure of reading comprehension (Smallwood, McSpadden, & Schooler, 2008). In a study of school-aged children with and without attention deficits, sustained attention, as measured by an inattention score from the Stop Signal task, predicted the ability to tell a story to an examiner using a picture book prompt, which requires comprehension skills as well as other abilities (Flory et al., 2006). In the same study, response inhibition did not predict storytelling performance. Across studies, these findings suggest that sustained attention contributes to both reading decoding and reading comprehension.

Cognitive Inhibition

Cognitive inhibition is associated with the "intentional" control of mental processes involved in suppressing unwanted or irrelevant thoughts and context-inappropriate meanings, as well as gating task-irrelevant information from working memory (Nigg, 2000; Wilson & Kipp, 1998). Although closely linked to working memory, cognitive inhibition has been identified as a unique executive function, acting to monitor and update the contents of working memory rather than simply acting in a storage and processing capacity (Miyake et al., 2000; Palladino & Ferrari, 2013). Directed-forgetting tasks that require the intentional suppression of specified words are thought to measure cognitive inhibition (Wilson & Kipp, 1998). Successful suppression of irrelevant information from working memory is presumed to be important for reading because it prevents context-irrelevant information from interfering with the development of an accurate mental representation of the text (Gernsbacher & Faust, 1991).

Poor comprehenders have been shown to have problems suppressing irrelevant information, suggesting that poor comprehension is related to poor cognitive inhibition, in individuals whose comprehension deficits do not arise from underlying decoding problems (Barnes, Faulkner, Wilkinson, & Dennis, 2004; Pimperton & Nation, 2010). Using a task designed to assess the ability to suppress no longer relevant information from working memory, Pimperton and Nation

(2010) found that poor comprehenders are more likely to recall a distracter word that is semantically related to the target word (an animal word, such as *dog*, they have been directed to forget from a previous list in order to recall *cat* from the current list) more often than good comprehenders. In contrast, good and poor decoders have not been found to differ on measures of cognitive inhibition (Chiappe, Hasher, & Siegel, 2000). These findings suggest that weak cognitive inhibition skills in poor comprehenders may result in the poor regulation of the contents of working memory, which has consequences for reading comprehension.

CURRENT STUDY

Although working memory and attentional control have been shown to be important for proficient reading, little is known about how each function of attentional control is differentially related to decoding versus reading comprehension. In addition, many studies have been conducted with children with reading and/or attention problems, which may not generalize to how these processes are related to reading in typically developing individuals. For example, studies of children with reading and/or attention difficulties suggest that response inhibition and reading decoding are related, in contrast to studies of typically developing children (de Jong et al., 2009 vs. Christopher et al., 2012). With the exception of Christopher et al. (2012), most studies have not investigated the relation of attentional control processes to both reading decoding and reading comprehension in the same individuals. Furthermore, most studies look at only one or two of these attentional control processes, and some studies do not differentiate or assess both response inhibition and cognitive inhibition (e.g., Christopher et al., 2012). Research has yet to examine the relation of all three attentional control functions in relation to typically developing decoding skills and reading comprehension. Although working memory and the attention control processes just reviewed appear to be related to either/or both reading decoding and reading comprehension, several aspects of these relations are not well understood, and there are some inconsistencies across studies.

In the current study, we were interested in the unique contributions of specific attentional control processes to reading comprehension and word decoding, when also accounting for working memory, in a large sample of typically developing children. This study is unique because it included measures of three potentially separable functions of attentional control rather than one global construct of attentional control or inhibition. Thus, we can explore how each of these functions of attentional control contributes to decoding and reading comprehension. Using a path analysis, we hypothesized that sustained attention and cognitive inhibition, but not response inhibition, would uniquely predict reading comprehension (Hypothesis 1). This would be indicated by significant direct effects of cognitive inhibition and sustained attention on reading comprehension in the path model. We also hypothesized that each function of attentional control would be differentially related to decoding with response inhibition, but not sustained attention or cognitive inhibition, significantly contributing to decoding (Hypothesis 2). Thus, significant direct effects of response inhibition on decoding would be observed in the path model.

METHOD

Participants

There were 1,763 students in Grades 6 through 12 from mainstream classrooms in four school districts within the greater Houston area who participated in the study. Students who consented were screened on word decoding and general intelligence. Selection was based in part on performance on the previous year's administration of Texas Assessment of Knowledge of Skills (TAKS), the state reading accountability test and a reliable and valid measure of reading comprehension (Cirino et al., 2013). Students were randomly selected from subgroups who met or did not meet benchmark criteria on the TAKS because of poor reading ability. We randomly selected students within each group, but oversampled students with poor TAKS performance, so that 56% of the sample passed and 44% did not pass. Students were excluded from participation if their school identified them as Limited English Proficient, if their reading instructor or English Language Arts instruction was provided by a Limited English Proficient teacher, or if they had a significant disability such as school-identified intellectual–cognitive disabilities, severe behavioral disabilities, or autism. Students who scored at or above the 20th percentile on the Woodcock–Johnson III (WJIII) Tests of Achievement, Letter Word Identification (Letter Word ID) subtest (Woodcock, McGrew, & Mather, 2001) and had a verbal and/or fluid intelligence score at or above 70, as determined by the Kaufman Brief Intelligence Test–2 (K-BIT-2; Kaufman & Kaufman, 2004) were eligible to continue the study. In total, 166 students refused consent and 411 students were disqualified due to low word reading. Students who passed the screening measures were then tested on a larger assessment battery. Those who successfully completed all relevant portions of the battery took part in this study. In total, 1,134 adolescent students (588 male) qualified and successfully completed the relevant tasks.

Procedures

As part of a larger study, each student was tested in a quiet area of the school for two or three sessions over a course of one week, based on availability. All tasks were administered by a member of the research team in accordance with standardized task administration procedures. The Gates–MacGinitie Reading Tests (GMRT; MacGinitie, MacGinitie, Maria, & Dreyer, 2000) Comprehension subtest was administered in a group setting. All other tasks were administered individually.

Measures

Reading comprehension. The GMRT Comprehension subtest (MacGinitie et al., 2000) is a group-administered assessment of reading comprehension for Kindergarten through adult populations. The task requires participants to read grade-appropriate passages of text silently and answer relevant comprehension questions within a 35-min time limit. Internal consistency reliability ranges from .91 to .93. GMRT total correct out of 45 was used in analyses as a measure of reading comprehension.

Decoding. The Phonemic Decoding Efficiency and the Sight Word Reading Efficiency subtests of the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) were used to assess word reading. The TOWRE is an individually administered assessment that measures students' ability to read words out of context. It consists of two timed measures, one of real-word reading, which measures students' ability to quickly name common words, and the other of pseudoword decoding, which measures students' ability to sound out words quickly and accurately. The internal consistency for both tests exceeds .95. A composite score combining the calculated raw scores of each TOWRE subtest, which reflects accuracy within a 45-s time limit on each subtest, was used as a measure of decoding ability.

Working memory. Working memory was assessed using the Numbers Reversed subtest of the WJIII Tests of Cognitive Abilities (Woodcock et al., 2001). The WJIII Numbers Reversed subtest is part of a nationally standardized, individually administered battery of achievement tests. Internal consistency for the working memory task exceeds .90. In this task students are required to immediately recall a string of digits presented orally by the examiner and repeat them back in reverse order. The task begins with a set of trials consisting of a string of three digits each. Additional trials continue with strings getting progressively longer with each set of successful trials. The task is discontinued when the student responds incorrectly to three successive trials. A raw score consisting of the number of trials correct was used as a measure of working memory (Woodcock et al., 2001).

Response inhibition and sustained attention. Response inhibition and sustained attention were measured using the Stop Signal Paradigm, which is an individually administered, computerized choice, reaction-time task (Schachar & Logan, 1990). A Lenovo ThinkPad laptop with a 15-in. screen was used to administer the task using a Presentation application. The Stop Signal Paradigm required students to press a button whenever they saw a letter appear in the middle of a computer screen ("go" signal trials; Figure 1). Using a game controller, students were required to press the top left button of the controller when the letter X appeared on the screen, and the top right button when the letter O appeared on the screen. Students were instructed to respond as quickly but as accurately as possible when a letter appeared. However, sometimes a beep sound immediately followed the letter. When students heard a beep, they were required to inhibit their response ("stop" signal trials). Generally, the shorter the delay between seeing a letter and hearing a beep, the easier it is to inhibit a response.

The timing of the stop signal (i.e., the delay between the go signal and the stop signal) is adaptive and based on the independent horse-race model developed by Logan (1981). Consequently, in stop signal trials, if students correctly inhibit their response, then the delay time between the go signal (letter) and the stop signal (beep) in the following stop signal trial is increased by 50 ms, making it increasingly harder for students to inhibit their response. This is the case every time students correctly inhibit their response in a stop signal trial. Conversely, every time students respond incorrectly in a stop signal trial, (i.e., press the button) the delay decreases by 50 ms in the following stop signal trial, making it increasingly easier for students to inhibit their response. The sequence of presentation of stop signal trials and go signal trials are random and adaptive to ensure the student is accurate on stop signal trials 50% of the time with the stop signal trials appearing 25% of all trials (six trials per block). Students complete one practice block and four test blocks that consist of 24 trials per block.

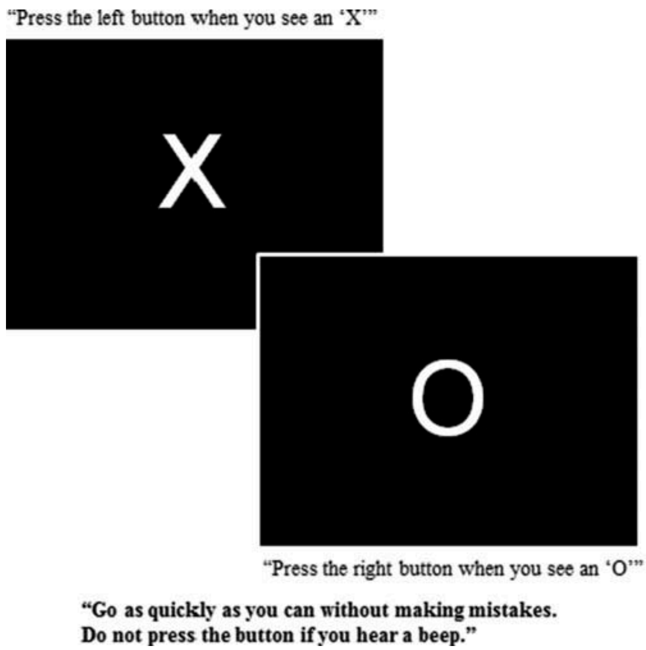

FIGURE 1 Sample stimuli from Stop Signal Paradigm measuring response inhibition and sustained attention.

Response inhibition scores are derived using the SSRT score, which is computed using the stop signal delay score minus the mean go reaction time (Schachar & Logan, 1990). Stop Signal inattention was used as a measure of sustained attention, obtained by standardizing and combining the standard deviation of reaction times to all go signal trials and the number of go signal trials not responded to (Flory et al., 2006). This derivation results in a score that reflects both omission errors and variability in the time to respond to targets, providing a measure of delay aversion representative of inattention (see Castellanos & Tannock, 2002).

Cognitive inhibition. The computerized Verbal Proactive Interference (VPI) task was used to assess cognitive inhibition (Pimperton & Nation, 2010). This task was individually administered on a Lenovo ThinkPad laptop with a 15-in. screen, using an EPrime application.

The task comprised four practice trials and 24 test trials, with both types of trials consisting of either a single- or double-block structure. Eight single-block trials were included to ensure that students paid attention to the first set of words, in addition to the second set in the 16 double-block trials.

Each trial began with a visual prompt "Ready?" that was followed directly by an audible list of four stimulus words. In the single-block trials, a list of words was followed by the appearance of a question mark (?) on the screen. In the double-block trials, the list of words was followed by the appearance of an X on the screen, then the presentation of a second list of four words, and finally a question mark (Figure 2). The appearance of an X on the screen indicated to students that they were to forget the first list of four words and instead focus on remembering the second list of

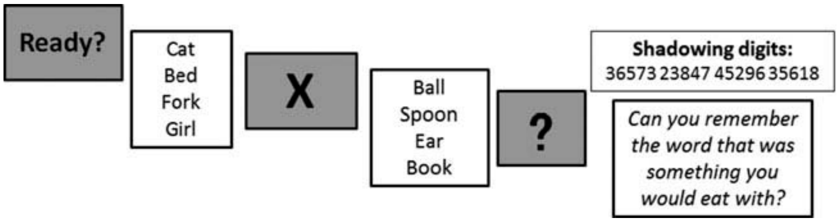

FIGURE 2 Sample stimuli for double block trial with interference from the Verbal Proactive Interference task measuring cognitive inhibition. *Note.* Gray blocks represent visual stimuli presented on the computer screen. White blocks represent auditory stimuli presented either via the computer or by the examiner.

four words. In both the single- and double-block trials, directly following the completion of the final word list and the appearance of the question mark, students were required to shadow a list of 20 numbers, presented verbally by the examiner to prevent rehearsal. To make the task more difficult for older students, a larger set of numbers was used than in Pimperton and Nation (2010). Immediately after shadowing, students were asked to recall a word from the list in response to a category cue (e.g., Can you remember the word that was a type of pet?). The examiner recorded the each student's responses.

Half of the 16 double-block trials consisted of "interference" trials, whereas the other half consisted of "no-interference" trials. In the no-interference trials, a word matching the category cue (e.g., type of pet) was presented in the second block of words only (e.g., with the target word *dog*). In the interference trials, both the first list (e.g., with the foil word *cat*) and the second list (with the target word *dog*) contained a category cue matching word. Students' responses were scored as correct if they were able to successfully produce the target word.

A measure of cognitive inhibition was provided by the number of interference trials correctly responded to out of eight (Pimperton & Nation, 2010). Reliability coefficients for the interference trials (Kuder-Richardson 20) range from .45 to .67 ($M = .63$).

Data Analyses

The direct and indirect effects of working memory and each function of attention control (response inhibition, sustained attention, and cognitive inhibition) on decoding and reading comprehension were examined. The bootstrap process was used to obtain confidence intervals for the parameter estimates of all indirect effects. The moderating effects of each function of attentional control and working memory were also included in the model. Age was included as a covariate in the model. All analyses were carried out using Mplus (Version 7; Muthén & Muthén, 1998–2012).

RESULTS

Preliminary Data Analyses

Descriptive statistics. Table 1 provides means and standard deviations for age, working memory, and attentional control variables, as well as reading comprehension and decoding

TABLE 1
Descriptive Statistics for All Variables by Grade

Variable	*6*[a] M (SD)	*7*[b] M (SD)	*8*[c] M (SD)	*9*[d] M (SD)	*10*[e] M (SD)	*11*[f] M (SD)	*12*[g] M (SD)
Age (years)	11.3 (.5)	12.5 (.6)	13.6 (.6)	14.6 (.6)	15.6 (.7)	16.7 (.6)	17.6 (.7)
GMRC	775.5_{a} (160.6)	784.6_{a} (164.8)	852.0_{b} (132.7)	878.9_{b} (182.6)	996.5_{c} (140.6)	983.1_{c} (143.4)	1016.4_{c} (160.6)
TOWRE	102.7_{a} (12.2)	$98.2_{a,b}$ (12.4)	$95.5_{b,c}$ (11.3)	$94.5_{b,c}$ (12.2)	92.5_{c} (12.1)	$90.2_{c,d}$ (10.7)	87.6_{d} (9.9)
WJIIINR	$12.7_{a\dot{}c}$ (2.5)	12.4_{a} (3.1)	13.7_{a} (3.5)	$13.7_{a,b}$ (3.5)	$13.6_{a,b}$ (2.9)	$13.7_{a,b,c}$ (3.6)	14.2_{b}(3.3)
SSRT	317.9_{a} (83.1)	$306.4_{a,b}$ (104.8)	$281.5_{a,b,c}$ (84.8)	$278.8_{b,c}$ (93.7)	$278.8_{b,c}$ (93.7)	275.9_{c} (108.3)	$275.3_{b,c}$ (99.9)
SSINT	183.2_{a} (48.6)	180.7_{a} (46.2)	176.8_{a} (46.9)	173.8_{a} (46.8)	173.8_{a} (46.8)	180.3_{a} (48.7)	184.7_{a} (46.6)
SSOE	1.6_{a} (2.3)	1.6_{a} (3.1)	1.1_{a} (2.2)	1.3_{a} (2.8)	$.9_{a}$ (2.0)	1.1_{a} (2.4)	1.3_{a} (3.1)
SSGRT	772.0_{a} (135.0)	753.4_{a} (146.5)	773.6_{a} (153.6)	776.7_{a} (164.9)	772.9_{a} (170.5)	766.7_{a} (164.1)	792.6_{a} (178.3)
SSRTV	181.6_{a} (47.4)	179.1_{a} (45.1)	176.9_{a} (41.9)	175.5_{a} (46.4)	172.9_{a} (46.4)	179.3_{a} (48.5)	183.4_{a} (46.8)
VPI	3.7_{a} (1.4)	$3.8_{a,b}$ (1.5)	4.1_{a} (1.8)	$4.4_{a,c}$ (1.7)	$4.4_{b,c}$ (1.7)	$4.2_{a,c}$ (1.6)	4.7_{c} (1.8)

Note. Means with the same subscript are not significantly different ($p < .05$). GMRC = Gates–MacGinitie Reading Tests Comprehension; TOWRE = Test of Word Reading Efficiency; WJIIINR = Woodcock–Johnson III Tests of Cognitive Abilities Numbers Reversed; SSRT = Stop Signal reaction time; SSINT = Stop Signal inattention; SSOE = Stop Signal omission errors; SSGRT = Stop Signal mean Go reaction time; SSRTV = Stop Signal reaction time variability; VPI = Verbal Proactive Interference.

[a]$n = 116$. [b]$n = 163$; VPI $n = 162$. [c]$n = 173$. [d]$n = 177$. [e]$n = 192$; TOWRE and VPI $n = 191$. [f]$n = 177$; TOWRE $n = 174$, WJIIINR, $n = 175$, VPI $n = 176$. [g]$n = 136$.

TABLE 2
Intercorrelations Among Variables

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. Age (years)	—									
2. GMRC	−.04	—								
3. TOWRE	−.41†	.31†	—							
4. WJIIINR	.14†	.29†	.20†	—						
5. SSRT	−.13†	−.05	−.06*	−.06*	—					
6. SSINT	−.004	−.09**	−.03	−.07*	.03	—				
7. SSOE	−.6*	−.07*	.06*	.03	−.05	.22†	—			
8. SSGRT	.06*	−.004	−.03	.01	−.03	.49†	.07*	—		
9. SSRTV	.007	−.09**	−.04	−.07*	.04	.99†	.17†	.50†	—	
10. VPI	.13†	.06*	.02	.22†	−.03	−.03	−.03	−.03	.03	—

Note. GMRC = Gates–MacGinitie Reading Tests Comprehension; TOWRE = Test of Word Reading Efficiency; WJIIINR = Woodcock–Johnson Tests of Cognitive Abilities Numbers Reversed; SSRT = Stop Signal reaction time; SSINT = Stop Signal inattention; SSOE = Stop Signal omission errors; SSGRT = Stop Signal mean Go reaction time; SSRTV = Stop Signal reaction time variability; VPI = Verbal Proactive Interference

*Significant at $p < .05$. **Significant at $p < .01$. †Significant at $p < .0001$.

measures by grade. Component scores (mean Go RT, RT variability, and omission errors) for composite Stop Signal variables are also included in Table 1. Mean scores for each of the tasks were broadly within the expected range. Analysis of variance of each measure indicated statistically significant effects of grade for all measures ($p < .001$), with the exception of Stop Signal inattention. Follow up Tukey's tests were conducted to identify significant differences between grade levels ($p < .05$). Table 1 shows a consistent pattern of higher scores with increasing grade levels for most tasks but relatively few differences between adjacent grades.

Relations of attentional control, working memory, and reading. Relations between performance on GMRT comprehension, TOWRE decoding, WJIII Numbers Reversed, and tasks measuring attentional control were examined using Pearson's correlation coefficients, reported in Table 2. As expected, GMRT comprehension was positively correlated with the TOWRE decoding. GMRT comprehension and TOWRE decoding were also positively correlated with WJIII Numbers Reversed. Stop Signal SSRT and Stop Signal inattention had weak, negative correlations with WJIII Numbers Reversed. VPI interference (total correct interference trials) was positively correlated with WJIII Numbers Reversed. The three measures of attention control were not significantly correlated with one another, indicating a lack of redundancy in measures of attentional control.

GMRT comprehension was significantly correlated with Stop Signal inattention and VPI interference. Stop Signal inattention was correlated with GMRT comprehension. Stop Signal SSRT was not significantly correlated with GMRT comprehension, but was correlated with TOWRE decoding.

Modeling the Attentional Control Predictors of Decoding and Reading Comprehension

A path analytic model was used to examine the direct and indirect effects of working memory, response inhibition, sustained attention, and cognitive inhibition on decoding and reading comprehension. Because previous research suggested a relation between decoding and response inhibition compared to relations of reading comprehension with sustained attention and cognitive inhibition, the path model used observed variables including Stop Signal SSRT as a moderator of the relation between WJIII Numbers Reversed and TOWRE decoding, and Stop Signal inattention and VPI interference as moderators of the relation between WJIII Numbers Reversed and GMRT comprehension. Age was included in the model as a covariate to account for developmental changes associated with the other measures. Figure 3 reports the results of the direct and indirect effects of working memory and attentional control on reading comprehension and decoding, as well as the moderating effects of attentional control and working memory.

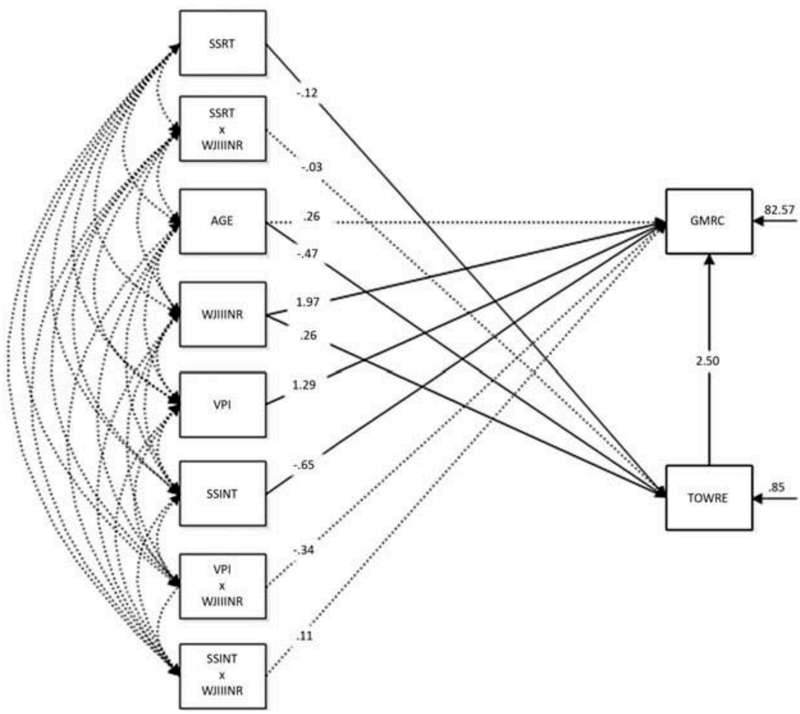

FIGURE 3 Path model representing response inhibition as a moderator of the relation between working memory and decoding, and cognitive inhibition and sustained attention as moderators of relation between working memory and reading comprehension. *Note.* GMRC = Gates–MacGinitie Reading Tests Comprehension; TOWRE = Test of Word Reading Efficiency; Age = age in years; WJIIINR = Woodcock–Johnson III Tests of Cognitive Abilities Numbers Reversed; SSRT = Stop Signal reaction time; SSINT = Stop Signal inattention; VPI = Verbal Proactive Interference. Solid lines represent statistically significant effects. Dashed lines represent effects that are not statistically significant.

Direct effects of TOWRE decoding ($b = 2.50$, $p < .001$) and WJIII Numbers Reversed ($b = 1.97$, $p < .001$) on GMRT comprehension were statistically significant. Consistent with Hypothesis 1, direct effects of VPI interference ($b = 1.29$, $p < .001$) and Stop Signal inattention ($b = -.65$, $p = .018$) on GMRT comprehension were also statistically significant. In addition, the indirect effect of WJIII Numbers Reversed on GMRT comprehension through TOWRE decoding ($b = .65$), 95% CI [.48, .88], was statistically significant. The direct effect of age ($b = .26$, $p = .39$) on GMRT comprehension was not statistically significant. Moderating effects of WJIII Numbers Reversed with VPI interference and Stop Signal inattention ($b = -.34$, $p = .22$ and $b = .11$, $p = .678$, respectively) were not statistically significantly.

The direct effects of WJIII Numbers Reversed ($b = .26$, $p < .001$), age ($b = -.47$, $p < .001$), and Stop Signal SSRT ($b = -.12$, $p < .001$) on TOWRE decoding were statistically significant. The moderating effects of WJIII Numbers Reversed and Stop Signal SSRT ($b = -.03$, $p = .25$) were not significant.

Alternative Models

Reverse path analysis. Our main path analyses were driven by previous research suggesting relations between decoding and response inhibition compared to those between reading comprehension and sustained attention and cognitive inhibition. To further assess the differential relation of attentional control and reading outlined by our hypotheses, an alternative model was used to assess response inhibition as a moderator of the relation between working memory and reading comprehension, as well as cognitive inhibition and sustained attention as moderators of the relation between working memory and decoding. Figure 4 represents the alternative, reverse path analyses. Consistent with model 1, the direct effect of WJIII Numbers Reversed on GMRT Comprehension was significant ($b = 2.23$, $p < .001$). There was a significant direct effect of WJIII Numbers Reversed ($b = .26$, $p < .001$) and age ($b = -.46$, $p < .001$) on TOWRE Decoding. The indirect effect of WJIII Numbers Reversed on GMRT Comprehension through TOWRE Decoding was significant ($b = .65$), 95% CI [.48, .88]. No other paths in the model were significant.

Path analysis with WJIII Letter Word ID as a measure of decoding. Our sample came from a larger study which selected participants based on performance on the WJIII Letter Word ID subtest. Therefore, the analyses just reported used a decoding composite that consisted of timed real-word and pseudoword measures from the TOWRE to reduce the likelihood of a truncated effect of decoding. However, because Christopher et al. (2012) used word recognition tasks scored for accuracy in their latent variable analysis, we replicated our path model with WJIII Letter Word ID as a measure of reading accuracy. All paths produced similar results to those just reported using word reading efficiency. Most important, there was a significant direct effect of Stop Signal SSRT on WJIII Letter Word ID ($b = -.34$, $p = .004$). There were additional significant direct effects of WJIII Numbers Reversed ($b = 1.27$, $p < .001$) and age ($b = 2.20$, $p < .001$) on WJIII Letter Word ID. An indirect effect of WJIII Number Reversed on GMRT Comprehension through WJIII Letter Word ID was also significant ($b = 1.068$), 95% CI [.81, 1.32].

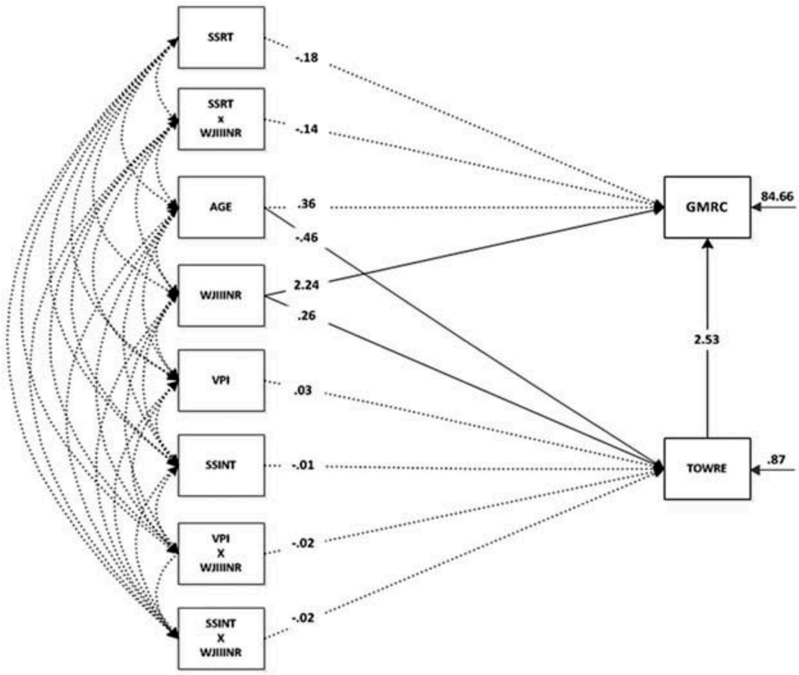

FIGURE 4 Path model representing response inhibition as a moderator of the relation between working memory and reading comprehension, and cognitive inhibition and sustained attention as moderators of relation between working memory and decoding. *Note.* GMRC = Gates–MacGinitie Reading Tests Comprehension; TOWRE = Test of Word Reading Efficiency; Age = age in years; WJIIINR = Woodcock–Johnson III Tests of Cognitive Abilities Numbers Reversed; SSRT = Stop Signal reaction time; SSINT = Stop Signal inattention; VPI = Verbal Proactive Interference. Solid lines represent statistically significant effects. Dashed lines represent effects that are not statistically significant.

DISCUSSION

Previous research has examined the relation of three functions of attentional control—response inhibition, sustained attention, and cognitive inhibition—and their relation to working memory and reading, but it has been unclear whether each function differentially relates to reading comprehension versus decoding because one global construct of attention control or inhibition has typically been used, rather than measures of three potentially separable functions of attentional control. By individually assessing each function of attentional control, we were able to assess the unique effects of each on reading comprehension versus reading decoding. We hypothesized that attentional control would be differentially related to reading comprehension versus decoding.

Our path analyses evaluated the direct and indirect effects of working memory and each function of attentional control to typically developing reading comprehension and word decoding abilities. Results indicated significant direct effects of working memory, sustained attention, and cognitive inhibition, but not response inhibition, on reading comprehension, as well as significant direct effects of working memory and response inhibition on decoding. There was also a significant indirect effect of working memory to reading comprehension, through decoding.

In addition, a direct effect of age on decoding was observed. Christopher et al. (2012) found that the relation between age and measures of reading were consistent across development. This is consistent with our findings supporting a similarly consistent increase in scores across grade level. This would suggest that the effects observed in our path analyses would be fairly consistent across development. Results of the current study were consistent with our hypotheses and overall offer new insight into the relation of attentional control to reading comprehension and decoding as separable components of reading proficiency.

Role of Working Memory in Reading

Working memory is significantly related to decoding and reading comprehension when also accounting for other cognitive constructs such as naming speed, processing speed (Christopher et al., 2012), reading fluency, vocabulary skills, planning skills (Sesma et al., 2009), and short-term memory (Swanson, 1993). Consistent with previous literature, the present study indicates direct effects of working memory on both single word decoding and comprehension of longer text. Although predictive of both decoding ability and reading comprehension, working memory may, however, operate differently with respect to these two reading skills (Catts et al., 2006; Christopher et al., 2012; Cutting et al., 2009; Locascio et al., 2010; Swanson et al., 2006). Although working memory is a major cognitive correlate of reading, it is not necessarily the strongest predictor of reading ability, when also accounting for fluency and reasoning ability, particularly in adolescent students similar to those of the current study (Tighe & Schatschneider, 2014). The unique contribution of each function of attentional control to reading comprehension versus decoding could account for differences in reading ability, independent of working memory skills (Henderson, Snowling, & Clark, 2013; Palladino & Ferrari, 2013; Pimperton & Nation, 2010). Results of the current study support this hypothesis, with significant direct effects of attentional control to both reading comprehension and decoding but no significant moderating effects of attentional control and working memory on reading.

Role of Response Inhibition, Sustained Attention, and Cognitive Inhibition in Reading Comprehension

Response inhibition, cognitive inhibition, and sustained attention, in addition to working memory, have been related to reading comprehension in other studies (Borella, Carretti, & Pelegrina, 2010; Friedman & Miyake, 2004; Gernsbacher & Faust, 1991; Palladino & Ferrari, 2013), but their overlapping and independent relations to reading have been difficult to discern because all these skills are not always assessed within one study; studies do not always distinguish between inhibitory processes assessed using directed forgetting, suppression, and response inhibition paradigms; and some studies evaluate the role of these factors in reading comprehension without reference to decoding. The models tested in the current study indicated significant direct effects of cognitive inhibition and sustained attention on reading comprehension. On the other hand, there was no significant effect of response inhibition on reading comprehension, nor were there moderating effects of working memory and attentional control on reading comprehension. These results suggest that both cognitive inhibition and sustained attention play a unique role in reading comprehension, independent of working memory. These findings are also consistent with Christopher et al. (2012), who found that working memory, but not response inhibition, was related to reading comprehension when also controlling for word reading ability or other cognitive correlates such as naming and processing speed.

Updating and maintenance of working memory requires adequate sustained attention to ensure that focus is maintained on task-relevant information, so as not to overtax working memory with distracter information. Sustained attention allows for the continued focus on context-relevant information, which in turn facilitates development of a coherent understanding of the text. Poor reading comprehension may, in part, be the result of an inability to focus attention on the text, which leads to difficulties with the processing and maintenance of information in working memory (Flory et al., 2006; Silva-Pereyra et al., 2010).

Efficient cognitive inhibition skills are also required in order that working memory does not become overwhelmed with information that is no longer relevant to constructing an accurate mental representation of the text. Although results of the current study indicate that cognitive inhibition is significantly correlated with working memory, consistent with previous research, our findings also indicate that cognitive inhibition is a distinct executive function apart from working memory (Miyake et al., 2000; Palladino & Ferrari, 2013) and plays a unique role in the contribution to reading comprehension (Henderson et al., 2013; Pimperton & Nation, 2010). In the Structure-Building Framework model of reading comprehension, suppression is identified as the mechanism that works to dampen irrelevant or inappropriate meanings of text (Gernsbacher, 1996). As text is read, related information, such as irrelevant meanings of ambiguous words, or world knowledge that is not relevant to the context can become activated in working memory. Adequate suppression or cognitive inhibition might be important for reducing the probability that irrelevant (or no longer relevant) information maintained in working memory, which in turn, may reduce the inclusion of contextually irrelevant information in the mental representation of the text as reading unfolds over time.

Both cognitive inhibition and sustained attention, therefore, may facilitate successful reading comprehension, because they act to regulate the contents of working memory while reading. These functions of attentional control were significantly related to reading comprehension as well as working memory, suggesting that the ability to sustain attention on contextually relevant information and inhibit or suppress contextually irrelevant information during reading is important for comprehension.

Role of Response Inhibition, Sustained Attention, and Cognitive Inhibition in Decoding

Like reading comprehension, working memory is also significantly related to decoding (Christopher et al., 2012; Swanson et al., 2009). Although Christopher et al. (2012) found that working memory, but not response inhibition, was significantly related to both reading comprehension and decoding, and Locascio et al. (2010) reported that response inhibition was no longer a significant predictor of decoding ability after accounting for phonological processing, we found that working memory and response inhibition both had direct effects on decoding.

In the case of decoding, response inhibition could be related to the inhibition of words that are orthographically similar to the word being read. When a word is read, neighboring words (those that are orthographically similar) can become temporarily activated (Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Response inhibition, as an automatic process, may be involved in inhibiting the activation of these neighboring words, particularly in the case of lower frequency words with exceptional spelling-sound mappings (e.g., pint vs. hint, pant). Response inhibition may serve as a gating mechanism that is responsible for the inhibition of irrelevant information before it enters into working memory. This would be opposed to cognitive inhibition, which is an effortful and intentional process that operates on information after it is processed in working memory. Results of the current study suggest that response inhibition may be related to the ability to adequately inhibit the response to orthographically similar words before they enter into working memory for further processing.

Other research has suggested that the significant relation between decoding and response inhibition may lie in the shared variance between response inhibition and processing speed, which may also be related to decoding efficiency (Purvis & Tannock, 2000). Christopher et al. (2012) found that processing speed accounted for unique variance in word reading, but not reading comprehension, after accounting for working memory and response inhibition. Because the Stop Signal Paradigm requires the rapid processing of visual stimuli, it is possible that the relation between SSRT and word reading efficiency may be related to processing speed, which was not accounted for in our models. However, our results were similar for word reading accuracy and decoding. In addition, de Jong et al. (2009) found that decoding difficulties were not related to deficits in processing speed. Further research should examine the relation of measures of processing speed and response inhibition and their relation to decoding.

The role of attentional control in both reading and working memory may account for the differing relations of working memory with reading comprehension and decoding. Our results indicate that response inhibition is not significantly related to working memory. As such, it may not play an active role in the maintenance of contents of working memory, a finding supported by Christopher et al. (2012).

Limitations

The current study has high statistical power due to a large sample size, which may permit detection of small effects, so that the relations detected in the current study are relatively small. Additional research is needed to confirm and further expand upon the distinct relation between attentional control and reading comprehension versus decoding.

We used only one task to assess each function of attentional control. Ideally, each function would be measured by multiple tasks designed to assess the same construct. The use of multiple tasks per construct would allow for the use of a confirmatory factor analysis to verify the existence of three distinct functions of attentional control, such as in Christopher et al. (2012).

Relatedly, further research is needed on the extent to which working memory tasks, particularly verbal working memory tasks such as the one used in the current study, relate to reading comprehension. Measures such as the VPI task, used in this study, contain a verbal component that may account for the relation observed between working memory and reading comprehension. Pimperton and Nation (2010) found that the effects of inhibition were not present in a nonverbal directed forgetting task suggesting that the relation between working memory, attentional control, and reading comprehension may reside primarily in the verbal domain. However, the use of nonverbal tasks, such as the Stop Signal Paradigm in the analyses, account for the linguistic component and allows for the interpretation of a relation between attentional control and not an underlying verbal component of the measures.

Implications and Future Directions

Understanding the differential role of cognitive processes such as working memory and attentional control in decoding and comprehension may help to better differentiate the role of decoding and comprehension in reading proficiency. Swanson (1993, 1999) identified both central executive and phonological processing elements of Baddley's (1992) model of working memory as key components of reading comprehension. Students with reading comprehension deficits resulting from poor decoding skills have shown significant problems in both reading comprehension and executive functioning that could not be accounted for by long-term memory, phonological processing skills, or working memory capacity. Swanson (1999) suggested that the reading comprehension deficits of these poor decoders could be the result of poor allocation of attentional control resources. The results of the current study indicate attentional control is differentially but significantly related to both comprehension and decoding. This suggests that the poor allocation of attentional control resources associated with the central executive could negatively impact comprehension as well as decoding.

Understanding the exact nature of how attentional control affects the development of a coherent representation of text can be instrumental in informing successful reading interventions, particularly for students with working memory and attentional control deficits (e.g., Holmes, Gathercole, & Dunning, 2009). Interventions designed to target working memory and some aspects of attentional control have previously been implemented in an attempt to improve reading ability (Dahlin, 2011; Morrison & Chein, 2011; Solan Shelley-Tremblay, Ficarra, Silverman, & Larson, 2004). Conversely, a meta-analysis conducted by Melby-Lervag and Hulme (2012) found that working memory training improved working memory performance but provided no significant improvements in other cognitive abilities or academic achievement (i.e., verbal ability, arithmetic, decoding, or reading comprehension). Identifying and targeting deficits in working memory alone may not provide the best means for improving reading skills, either for decoding or reading comprehension. Johnson and Swanson (2011) found that there were no significant differences in working memory in those students who responded to a reading intervention and those who did not. However, in the same study, high responders outperformed both low responders and nonresponders on the Attention subscales of the Cognitive Assessment System. These findings suggest that differences in attentional control might be useful for predicting the degree to which a student may respond to reading interventions.

It is an open question whether training that specifically develops working memory and attentional control can directly improve reading ability. However, understanding the differentiating role of attentional control and working memory may assist in identifying students who are less likely to respond to typical reading interventions, providing an opportunity for specialized intervention plans such as the inclusion of tasks that focus on improving the student's ability to identify and focus on task relevant content while inhibiting irrelevant information. Interventions that also include a focus on development of attentional control could assist in promoting the development of a stronger representation of text while reducing cognitive load and thus improving overall comprehension. Understanding the relation between attentional control and working memory in reading comprehension versus decoding has the potential to provide useful knowledge for the implementation of more specifically targeted reading interventions, particularly for those students who might not respond to typical reading interventions.

ACKNOWLEDGMENTS

We thank Hannah Pimperton for sharing materials for the Verbal Proactive Interference task.

FUNDING

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305F100013 to The University of Texas at Austin as part of the Reading for Understanding Research Initiative. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

REFERENCES

Aaron, P. G., Joshi, R. M., Palmer, H., Smith, N., & Kirby, E. (2002). Separating genuine cases of reading disability from reading deficits caused by predominantly inattentive ADHD behavior. *Journal of Learning Disabilities*, *35*, 425–436.

Alloway, T. P., Elliott, J., & Place, M. (2010). Investigating the relationship between attention and working memory in clinical and community samples. *Child Neuropsychology*, *16*, 242–254.

Astle, D., & Scerif, G. (2011). Interactions between attention and visual short-term memory (VSTM): What can be learnt from individual and developmental differences? *Neuropsychologia*, *49*, 1435–1445.

Baddeley, A. D. (1986). *Working memory*. New York, NY: Clarendon/Oxford University Press.

Baddeley, A. D. (1992). Working memory: The interface between memory and cognition. *Journal of Cognitive Neuroscience*, *4*, 281–288.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47–89). New York, NY: Academic Press.

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory* (pp. 28–61). Cambridge, UK: Cambridge University Press.

Barnes, M. A., Faulkner, H., Wilkinson, M., & Dennis, M. (2004). Meaning construction and integration in children with hydrocephalus. *Brain and Language*, *89*, 47–56.

Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin*, *130*, 553–573.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities*, *43*, 541–552.

Bosse, M., & Valdois, S. (2009). Influence of the visual attention span on child reading performance: A cross-sectional study. *Journal of Research in Reading*, *32*, 230–253.

Cain, K. (2006). Individual differences in children's memory and reading comprehension: An investigation of semantic and inhibitory deficits. *Memory*, *14*, 553–569.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology*, *96*, 31–42.

Castellanos, F. X., & Tannock, R. (2002). Neuroscience of attention-deficit/hyperactivity disorder: The search for endophenotypes. *Nature Reviews: Neuroscience*, *3*, 617–628.

Catts, H. W., Adlof, S. M., & Weismer, S.E. (2006). Language deficits in poor comprehenders: A case for the simple view of reading. *Journal of Speech and Hearing Research*, *49*, 278–293.

Chiappe, P., Hasher, L., & Siegel, L. S. (2000). Working memory, inhibitory control, and reading disability. *Memory & Cognition*, *28*, 8–17.

Christopher, M. E., Miyake, A., Keenan, J. M., Pennington, B., DeFries, J. C.,Wadsworth, S. J., . . . Olson, R. K. (2012). Predicting word reading and comprehension with executive function and speed measures across development: A latent variable analysis. *Journal of Experimental Psychology: General*, *141*, 470–487.

Cirino, P. T., Romain, M. A., Barth, A. E., Tolar, T. D., Fletcher, J. M., & Vaughn, S. (2013). Reading skill components and impairments in middle school struggling readers. *Reading and Writing*, *26*, 1059–1086.

Conners, F. A. (2009). Attentional control and the simple view of reading. *Reading and Writing*, *22*, 591–613.

Cutting, L. E., Materek, A., Cole, C. A., Levine, T. M., & Mahone, E. M. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia*, *59*, 34–54.

Dahlin, K. I. (2011). Effects of working memory training on reading in children with special needs. *Reading and Writing*, *24*, 479–491.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*, *3*, 422–433.

De Beni, R., & Palladino, P. (2000). Intrusion errors in working memory tasks. Are they related to reading comprehension ability? *Learning and Individual Differences*, *12*, 131–143.

de Jong, C. G., Van de Voorde, S., Roeyers, H., Raymaekers, R., Oosterlaan, J., & Sergeant, J. A. (2009). How distinctive are ADHD and RD? Results of a double dissociation study. *Journal of Child Psychology*, *37*, 1007–1017.

Flory, K., Milich, R., Lorach, E. P., Hayden, A. N., Strange, C., & Welsh, R. (2006). Online story comprehension among children with ADHD: Which core deficits are involved? *Journal of Abnormal Child Psychology*, *34*, 853–865.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General*, *133*, 101–135.

Gathercole, S. E., & Baddeley, A. D. (1993). *Working memory and language*. East Sussex, UK: BPCC Wheatons.

Gernsbacher, M. A. (1996). The structure-building framework: What it is, what it might also be, and why. In R. J. Gerrig (Eds.), *Models of understanding text* (pp. 289–311). Mahwah NJ: Erlbaum.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 245–262.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Reading and Special Education*, *7*, 6–10.

Henderson, L., Snowling, M., & Clarke, P. (2013). Accessing, integrating, and inhibiting word meaning in poor comprehenders. *Scientific Studies of Reading*, *17*, 177–198.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, *12*, F9–F15.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *2*, 127–160.

Johnson, D. E., & Swanson, H. L. (2011). Cognitive characteristics of treatment resistant children with reading disabilities: A retrospective study. *Journal of Psychoeducational Assessments*, *29*, 137–149.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman brief intelligence test* (2nd ed.). Minneapolis, MN: Pearson Assessment (K–BIT–2).

Locascio, G., Mahone, E. M., Eason, S. H., & Cutting, L. E. (2010). Executive dysfunction among children with reading comprehension deficits. *Journal of Learning Disabilities*, *43*, 441–454.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review*, *91*, 295–327.

MacGinitie, W. H., MacGinitie, R. K., Maria, K. & Dreyer, L. G. (2000). *Gates MacGinitie Reading Tests*. Rolling Meadows, IL: Riverside.

Melby-Lervag, M., & Hulme, C. (2012). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*, 270–291.

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review*, *18*, 46–60.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.

Muthén, L. K., & Muthén, B. O. (1998–2012). *Mplus User’s Guide* (7th ed.). Los Angeles, CA: Muthén & Muthén.

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychology: Views from cognitive and personality psychology and working inhibition taxonomy. *Psychological Bulletin*, *126*, 220–246.

Oakhill, J. (1993). Children’s difficulties in reading comprehension. *Educational Psychology Review*, *5*, 223–237.

Oakhill, J. V., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading*, *16*, 91–121.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes*, *18*, 443–468.

Palladino, P., & Ferrari, M. (2013). Interference control in working memory: Comparing groups of children with atypical development. *Child Neuropsychology*, *19*, 37–54.

Pimperton, H., & Nation, K. (2010). Suppressing irrelevant information from working memory: Evidence for domain-specific deficits in poor comprehenders. *Journal of Memory and Language*, *62*, 380–391.

Purvis, K. L., & Tannock, R. (2000). Phonological processing, not inhibitory control, differentiates ADHD and reading disability. *Journal of the American Academy of Child and Adolescent Psychiatry*, *39*, 485–494.

Rapp, D. N., van den Broek, P., McMaster, K. L., Kendeou, P., & Espin, C. A. (2007). Higher order comprehension processes in struggling readers: A perspective for research and intervention. *Scientific Studies of Reading*, *11*, 289–312.

Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children’s reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology*, *97*, 365–385.

Schachar, R., & Logan, G. D. (1990). Impulsivity and inhibitory control in normal development and child psychopatholgy. *Developmental Psychology*, *26*, 710–720.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior*, *23*, 383–404.

Seigneuric, A. & Ehrlich, M. (2005). Contribution of working memory capacity to children’s reading comprehension: A longitudinal investigation. *Reading and Writing*, *18*, 617–656.

Sesma, H. W., Mahone, E. M., Levine, T., Eason, S. H., & Cutting, L. E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology*, *15*, 232–246.

Silva-Pereyra, J., Bernal, J., Rodríguez-Camacho, M., Yáñez, G., Prieto-Corona, B., Luviano, L., . . . Rodríguez, H. (2010). Poor reading skills may involve a failure to focus attention. *NeuroReport*, *21*, 34–38.

Smallwood, J., Fishman, D. J., & Schooler, J. W. (2007). Counting the cost of an absent mind: Mind wandering as an under recognized influence on educational performance. *Psychonomic Bulletin & Review*, *14*, 230–236.

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory & Cognition*, *36*, 1144–1150.

Solan, H. A., Shelley-Tremblay, J., Ficarra, A., Silverman, M., & Larson, S. (2004). Effect of attention therapy on reading comprehension. *Journal of Optometric Vision Development*, *35*, 87–96.

Stenner, A. J., Burdick, H., Sanford, E. E., & Burdick, D. S. (2006). How accurate are lexile text measures? *Journal of Applied Measurement*, *7*, 307–322.

Swanson, H. L. (1993). Working memory in learning disability subgroups. *Journal of Experimental Child Psychology*, *56*, 87–114.

Swanson, H. L. (1999). Reading comprehension and working memory in learning-disabled readers: Is the phonological loop more important than the executive system? *Journal of Experimental Child Psychology*, *72*, 1–31.

Swanson, H. L. (2011). Dynamic testing, working memory, and reading comprehension growth in children with reading disabilities. *Journal of Learning Disabilities*, *44*, 358–371.

Swanson, H. L., Howard, C. B., & Saez, L. (2006). Do differences in components of working memory underlie different subgroups of reading disabilities? *Journal of Learning Disabilities*, *39*, 252–269.

Swanson, H. L., Zheng, X., & Jerman, O. (2009). Working memory, short-term memory, and reading disabilities: A selective meta-analysis of the literature. *Journal of Learning Disabilities*, *42*, 260–287.

Tighe, E. L., & Schatschneider, C. (2014). A dominance analysis approach to determining predictor importance in third, seventh, and tenth grade reading comprehension skills. *Reading and Writing*, *24*, 101–127.

Torgesen, J. K., Wagner, R., & Rashotte, C. (1999). *Test of Word Reading Efficiency*. Austin, TX: Pro–Ed.

van der Schoot, M., Licht, R., Horsley, T. M., & Sergeant, J. A. (2000). Inhibitory deficits in reading disability depend on subtype: Guessers but not spellers. *Child Neuropsychology*, *6*, 297–312.

Williams, B. R., Ponesses, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1999). Development of inhibitory control across the life span. *Developmental Psychology*, *35*, 205–213.

Wilson, S. P., & Kipp, K. (1998). The development of efficient inhibition: Evidence from directed-forgetting tasks. *Developmental Review*, *18*, 86–123.

Woodcock, R. W., McGrew, K., & Mather, N. (2001). *Woodcock–Johnson III Tests of Achievement*. Itasca, IL: Riverside.