The Role of Executive Functions in Reading Comprehension

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Keywords: Executive Functions, Reading Comprehension, Discourse Processes

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Abstract

Our goal in this paper is to understand the extent to which, and under what conditions, executive functions (EFs) play a role in reading comprehension processes. We begin with a brief review of core components of EF (inhibition, shifting, and updating) and reading comprehension. We then discuss the status of EFs in process models of reading comprehension. Next, we review and synthesize empirical evidence in the extant literature for the involvement of core components of EF in reading comprehension processes under different reading conditions and across different populations. In conclusion, we propose that EFs may help explain complex interactions between the reader, the text, and the discourse situation, and call for both existing and future models of reading comprehension to include EFs as explicit components.

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The Role of Executive Functions in Reading Comprehension

Executive functions (EFs) are a suite of cognitive abilities that modulate cognition. Three core EFs are *updating* working memory, *inhibiting* dominant responses, and *shifting* attention (Miyake et al., 2000). Our aim in this paper is to understand the extent to which, and under what conditions, these different EFs relate to reading comprehension theories and performance. To achieve this aim, first we identify and define basic components of EFs in the extant literature. Next, we review research in discourse processes to identify the status of EFs in prominent models and theories of reading comprehension. Following, we present the results of a systematic review of the extant literature to describe the ways in which three core EFs (i.e., updating, inhibition, shifting) relate to reading comprehension performance. We end with a set of conclusions and future directions that we hope will stimulate further work in this area.

Executive Functions: Components and Definitions

Broadly, EF is an umbrella term for a set of higher-order cognitive processes that modulate the dynamics of human cognition (Miyake et al., 2000). Overall, conceptualizations of EF have progressed from a unitary system (e.g., Supervisory Attention System; Norman & Shallice, 1986) to a set of different functions that ultimately allow for higher-level skills like planning and self-regulation to develop (e.g., Das, Naglieri, & Kirby, 1994; Denckla, 1996). Currently, one of the most prominent models of EF is that of Miyake et al., which contends that EF consists of at least three components, and that these components are separable, yet interrelated. *Updating* is the ability to actively monitor and update working memory contents. *Inhibition* is the ability to actively inhibit or suppress dominant responses. *Shifting,* also commonly referred to as *task* or *attention switching* and *cognitive flexibility,* is the ability to flexibly shift attention between mental sets, operations, or tasks. Miyake et al. found that although these three EF components were distinguishable, they were also moderately correlated and thus shared some underlying commonality. These three components were derived using a latent variable approach that included three measures for each of the three latent constructs. Specifically, updating was measured via a keep-track task (Yntema, 1963), a tone monitoring task (Larson, Merritt, & Williams, 1988), and a letter memory task (Morris & Jones, 1990); inhibition was measured via an anti-saccade task (Roberts, Hager, & Heron, 1994), a stop-signal task (Logan, 1994), and a Stroop task (Stroop, 1935); shifting was measured via a plus-minus task (Spector & Biederman, 1976), a number-letter task (Rogers & Monsell, 1995), and a local-global task (Navon, 1977).

More recently, Miyake and Friedman (2012) revisited this original model. In doing so, they conceptualized the unity and diversity among the components of EF. *Unity* among the three EF components is captured by the correlations among updating, inhibition, and shifting, indicating that there is a common cognitive ability that partially explains performance across the host of EF tasks the authors included in their analyses. The authors refer to this as *common EF,* which they describe as the ability to both actively maintain task goals and relevant information, and use this information to bias lower-level processing in favor of these goals. Although these components share considerable overlap, they are also separable. Miyake and Friedman found unique variance associated with updating and shifting, but not inhibition, which suggests that inhibition is entirely accounted for by *common EF*.

The three-component model of Miyake et al. (2000) has largely dominated research regarding the role of executive functions in reading comprehension, and it has been supported in diverse populations and contexts (e.g., Fisk & Sharp, 2004; Garon, Bryson, & Smith, 2008; Huizinga, Dolan, & van der Molen, 2006). For this reason, we organize this review following the three EF components in the Miyake et al. model. It is important to note, however, that the research reviewed also draws upon alternative models of EF (e.g., Baddeley & Hitch, 1974), or remains largely agnostic on models—that is, it does not explicitly endorse one model of EF over another, but instead focuses on individual EF components.

The Status of Executive Functions in Models of Reading Comprehension

Reading comprehension is one of the most complex and important cognitive activities humans perform (Kendeou, McMaster, & Christ, 2016). Given its importance and complexity, researchers have sought to understand reading comprehension via the development and specification of a multitude of models and frameworks that account for various processes and mechanisms of reading. Generally, reading comprehension refers to the construction of a mental representation of what the text is about (Kintsch & van Dijk, 1978). Although most models of reading comprehension converge on this general idea, the processes and assumptions by which readers construct such representations differ across models and frameworks. It is also important to note that a unified, comprehensive model of reading comprehension has yet to be established.

McNamara and Magliano (2009) reviewed and compared one set of models[1], which are concerned primarily with the construction of the mental representation during reading: The Construction-Integration Model (Kintsch, 1988), the Structure-Building Framework (Gernsbacher, 1991), the Resonance Model (Albrecht & O'Brien, 1993), the Event-Indexing Model (Zwaan, Langston, & Graesser, 1995), the Causal Network Model (Trabasso, van den Broek, & Suh, 1989), the Constructionist Theory (Graesser, Singer, & Trabasso, 1994), and the

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[1] In this review we focus only on this set of models (i.e., process models) as they are pertinent to the role of EF. It is important to note that a second set of models in the literature focuses on the identification of component skills (i.e., component models), linguistic and cognitive, that explain reading comprehension performance (Barnes, 2015). These models are not reviewed because they fall outside the scope of this paper.

Landscape Model (van den Broek, Young, Tzeng, & Linderholm, 1999). In this review, we investigate the status of EFs in each of these models.

Among this set of models, the Construction-Integration (CI) model (Kintsch, 1988) is perhaps the most comprehensive, and it is considered the best approximation to a true theory of reading comprehension (Kendeou & O'Brien, in press). According to the CI model, comprehension is the result of two processes, construction and integration. *Construction* refers to the activation of information in the text and background knowledge. There are four potential sources of activation: the current text input, the prior sentence, background knowledge, and prior text. As this information is activated, it is connected into a network of concepts. *Integration* refers to the continuous spread of activation within this network until activation settles. Activation sources from the construction process are iteratively integrated and only those concepts that are connected to many others are maintained in the network. At the completion of reading, the result is a complete network or a mental representation of what the text is about. This mental representation has been termed the *situation model*.

Even though the initial model makes no explicit reference to EFs, in a subsequent revision, Kintsch (1998) included a suppression mechanism in the CI model by adopting inhibitory links. Specifically, the CI model relies on links between information units to promote an appropriate representation of a text and inhibit inappropriate representations. In this context, facilitatory links connect related information units, and inhibitory (or negative) links connect conflicting or inappropriate information units. Inhibitory links serve to suppress or inhibit inappropriate representations (Kintsch, 1998).

The Structure-Building Framework (Gernsbacher, 1991) describes comprehension as the result of three processes. The first process, *laying a foundation*, involves using initial information from a text to lay the groundwork for a mental representation to be constructed. The second process, *mapping,* involves mapping information from the text onto that foundation to create "structures." The third process, *shifting,* involves a "shift" to begin building a new structure when readers are unable to map information onto an existing structure. Irrelevant information that does not cohere with a current structure is *suppressed*. Thus, within the Structure-Building Framework, the suppression mechanism attempts to account for individual differences in comprehension ability.

Specifically, the model posits that if incoming information is related to the current structure, then activation of that information is *enhanced,* resulting in its incorporation into the current structure. When information is not related to the current structure, then activation to that information is *suppressed*, or, alternatively, readers may *shift* and use that information to begin building a new structure. The suppression mechanism is the result of readers' ability to *inhibit* irrelevant information. This ability moderates reading comprehension in that skilled readers have a strong suppression mechanism and can therefore suppress irrelevant information, whereas less-skilled readers lack a strong suppression mechanism. As a result, less-skilled comprehenders' poor suppression ability may lead them to shift too often, which impairs comprehension because more information is competing for limited resources.

The Resonance Model (Myers & O'Brien, 1998) attempts to account for factors that influence the activation of information during comprehension, particularly information that is no longer active in working memory. The model emphasizes automatic, memory-based retrieval mechanisms as fundamental assumptions. Specifically, the model assumes that information in working memory serves as a signal to all of memory, which activates information that *resonates* with the signal. Elements resonate as a function of the number of features that overlap with the contents of working memory. Even though the model has not explicitly incorporated any EFs, O'Brien, Albrecht, Hakala, and Rizzella (1995) found that suppression was involved in processes relevant to the Resonance Model. Specifically, O'Brien et al. found that when an anaphoric phrase reactivated more than one potential antecedent from the text, the selected target antecedent was strengthened in long-term memory, whereas potential, but non-target, antecedents that interfered with the target antecedent were suppressed.

The Event-Indexing Model (Zwaan et al., 1995) was developed as an attempt to account more fully for processes involved with situation model construction of narrative texts. It operates under the assumption that readers monitor and establish coherence along five dimensions of continuity, and thus situation model construction: time, space, causality, motivation, and agents. Thus, within the event-indexing model, EFs such as shifting attention from one dimension to another, as well as updating the construction of the situation model account for individual differences in comprehension ability. For example, Bohn-Gettler, Rapp, van den Broek, Kendeou, and White (2011) found that there are developmental differences in children's ability to monitor the shifts in each of these dimensions.

The Causal Network Model (Trabasso et al., 1989) accounts for how readers generate causal inferences and represent causality during reading. Causal inferences are at the core of building a coherent representation of a story. Narrative elements can be categorized as either settings, events, goals, attempts, outcomes, or reactions. Also, there are assumed to be four types of causal relations: enabling, psychological, motivational, and physical. The model also provided a discourse analysis tool, Causal Network Analysis, to identify the causal structure that underlies story constituents. Overall, the model accounts for the importance of causal relations in memory for the text, but makes no assumptions about specific EFs.

The Constructionist theory (Graesser et al., 1994) attempts to account for factors that predict inference generation during reading. The theory emphasizes the role of top-down, strategic processes in the construction of meaning, what has been termed ‘search after meaning.’ Three assumptions define ‘search after meaning.’ The first is the reader goal assumption, which suggests that readers construct meaning in accordance with their reading goals. The second is the coherence assumption, which suggests that readers construct meaning at both local and global levels. The third is the explanation assumption, which suggests that readers are driven to construct meaning that explains events they read. Even though the theory makes no concrete assumptions about EFs, it is reasonable to assume that shifting attention likely exerts an influence on the top-down, strategic processes that govern ‘search after meaning.’

Lastly, the Landscape Model (van den Broek et al., 1999) simulates the fluctuation of concept activation during reading. The Landscape Model is similar to the CI Model in that it assumes the same four sources of activation. The model also includes two important mechanisms, cohort activation and coherence-based retrieval. Cohort activation assumes that when a concept is activated, all other concepts that are also activated become associated with it (McClelland & Rumelhart, 1985). Coherence-based retrieval assumes that the activation of text elements is in accordance with the readers’ standards of coherence. In turn, standards of coherence refer to readers’ implicit or explicit criteria for comprehension. Even though the Landscape Model makes no concrete assumptions about EFs, it is reasonable to assume that shifting likely exerts an influence on readers’ standards of coherence, directing attention to information that aligns with readers’ standards.

To conclude, although there is limited explicit reference to EFs in reading comprehension models and theories—with the exception of Gernsbacher’s Structure Building Framework

(Gernsbacher, 1991)—there is empirical evidence in support of the involvement of EFs in various aspects of reading comprehension in several of the aforementioned models. Next, we draw on the extant literature to describe the ways in which specific EF components support reading comprehension. We organize this literature review following the three-component model of Miyake et al (2000). We note that even though this model provides relatively narrow interpretations of updating, inhibition, and shifting, it helps organize extant findings in a coherent way. It is also important to note that the sections that follow are not wholly constrained to the interpretations of Miyake et al., but instead more generally capture the multidimensionality of updating, inhibition, and shifting functions in the context of reading comprehension.

Evidence for the Role of EFs in Reading Comprehension

To identify evidence for the relation between the three EF components and reading comprehension, we conducted literature searches using PsycINFO and Google Scholar search platforms in April 2016 and again in May 2017. For both searches, we included the following search terms: *executive functio** and *reading comprehension, updat** and *reading comprehension, suppress** or *inhibit** and *reading comprehension*, *shift** or *cognitive flexibility* and *reading comprehension, cognitive control* and *reading comprehension, central executive* and *reading comprehension*. These terms allowed us to search for different derivations of EF components (e.g., executive functions, executive functioning, and executive function).

This initial search yielded 276 articles. These entries were examined for population of interest. We excluded articles that focused exclusively on special populations (e.g., only populations with reading disability, developmental disability, ADHD, etc.), as our intent was to review the role of EF in reading comprehension in typically developed readers. However, we included studies that compared typical readers and readers with reading disabilities. We also excluded articles that did not directly measure EF components or reading comprehension, but instead used indirect measures or discussed EFs in the context of interpreting findings or describing future work. Because conceptualizations of EF vary, we also searched articles for the specific measures used. This is important because, for example, some authors use updating tasks, but conceptualize the construct more generally as “working memory” (e.g., Garcia-Madruga, Vila, Gomez-Viega, Duque, & Elosua, 2014). Only studies that examined EF constructs were included. Elimination based on these criteria resulted in retaining 45 articles. To facilitate our synthesis we created a table (Table 1) that includes the different EF component measures discussed in these studies along with a brief description and original reference.

Updating

The updating component of EF incorporates processes of working memory (Carretti, Cornoldi, De Beni, & Palladino, 2004). Thus, before we discuss work on updating and its relation to reading comprehension, a brief account of working memory is necessary. Baddeley’s multicomponent working memory model (Baddeley, 2000; Baddeley & Hitch, 1974) is a prominent model of working memory. Initially, Baddeley proposed that the model consists of three components: the phonological loop, the visuospatial sketchpad, and the central executive. The phonological loop stores verbal information, and the visuospatial sketchpad stores visual and spatial information. The central executive controls information processing by modulating the interactions between the two storage systems. Later, a fourth component was added, the episodic memory buffer, which manages the integration of information in working memory with information in long-term memory. Although the central executive was conceptualized as a unitary system, it has been proposed to actually reflect low-level executive functions, including inhibition, shifting, and updating (Baddeley 1996; 2003), as well as higher-level functions like planning (Baddeley, 1986, 1998; Cain, 2006).

Within Baddeley's working memory model, the phonological loop and the central executive components are particularly important for the role of updating in reading comprehension. Savage, Cornish, Manly, and Hollis (2006) found that performance on measures from the Working Memory Test Battery for Children (WMTB-C) for phonological loop (i.e. digit recall, word list matching/recall, non-word list recall tasks) and central executive processing (i.e. listening span, counting recall, backwards digit recall tasks) predicted reading comprehension, even after controlling for children’s attention, age, and IQ. Likewise, there is evidence that children who struggle with comprehension tend to underperform when demands are placed on both the phonological loop and the central executive (e.g., Swanson, 1999). From this evidence, it appears that the central executive may serve to constrain information in the phonological loop when sentences become longer and their syntactic structure becomes more complex. In such instances, readers with deficits in either the phonological loop or the central executive are likely to experience impaired comprehension due to an inability to cope with incoming information during reading.

It is important to note that the relation between working memory and updating is not straightforward. Some researchers have termed working memory itself as an executive function (e.g., Georgiou & Das, 2016; Guajardo & Cartwright, 2016; Kieffer, Vukovic, & Berry, 2013; Sesma, Mahone, Levine, Eason, & Cutting, 2009), which makes it unclear whether updating and working memory can be reliably distinguished. Working memory is often measured using complex span tasks (e.g., reading span, digit span, operation span, etc.; see Table 1 for a brief description). By contrast, updating is often measured using *n*-back or keep-track tasks, in which participants must evaluate each stimulus in a sequence for whether it matches a previously presented stimulus (Cohen et al., 1997). Kane, Conway, Miura, and Colflesh (2007) found only weak correlations (i.e., in the $r = .20$ range) between performance on complex span and letter *n*-back tasks. Likewise, a recent meta-analysis also showed that simple and complex span tasks related only weakly to *n*-back tasks (Redick & Lindsey, 2013). Pertinent to reading comprehension, Radvansky and Copeland (2001) found that even though complex span tasks were not strong predictors of the ability to successfully update situation models during reading, an updating task was a strong predictor. In fact, some researchers posit that the updating function may actually mediate the relation between working memory and reading comprehension (Carretti, et al., 2004; Gernsbacher, Varner, & Faust, 1990; Swanson et al., 2006).

Because there are still a lot of unanswered questions about the relation between working memory and updating (e.g., Kane Conway, Miura, & Colflesh, 2007; Schmiedek, Hildebrandt, Lovden, Wilhelm, & Lindenberger, 2009) and previous work has extensively examined the relation between working memory and reading comprehension (Budd, Whitney, & Turley, 1995; Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980; Hannon & Daneman, 2001; Just & Carpenter, 1992; Swanson, 1999; Turner & Engle, 1989; Waters, 1996), we concentrated our efforts in reviewing and understanding the relation of updating and reading comprehension. Comprehensive reviews about the relation of working memory and reading comprehension can be found elsewhere (e.g., Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Carpenter, 1980, 1983; Daneman & Merikle, 1996).

In perhaps the earliest investigation that has specifically examined updating in the context of reading, Palladino, Cornoldi, De Beni, and Pazzaglia (2001) found that updating is related to reading comprehension in both young adolescents and adults via an underlying mechanism that modulates the activation of information in working memory. Palladino et al. used a variant of Morris and Jones's (1990) updating task in which skilled and less-skilled comprehenders recalled the last four words from auditory lists of unknown lengths. Results showed that skilled comprehenders outperformed less-skilled comprehenders; however, the authors acknowledged that this finding may have been due to recency effects, or enhanced recall of the last items or information encoded (Davelaar, Gottstein, Ashkenazi, Haarman, & Usher, 2005), and not to updating deficiencies. To address this issue, in their second experiment the authors used a size-judgment task that demanded higher levels of semantic processing in an attempt to mitigate recency effects. Participants had to recall the last three-to-five smallest items from a list of objects, which required updating in that the last items were not necessarily the smallest items. Less-skilled comprehenders still underperformed and produced poorer recall and more intrusion errors (i.e., remembering relevant, but non-target, information) than skilled comprehenders. These results indicated that poor comprehenders may also be poor updaters who have difficulty updating relevant information across different updating tasks.

One key consequence of poor updating is the maintenance of irrelevant information in working memory. Irrelevant information that remains in working memory is likely to lead to intrusion errors. Carretti, Cornoldi, De Beni, and Romanó (2005) distinguished between two types of intrusion errors that occur in the context of an updating task structured after that of Palladino et al (2001). An *immediate intrusion* is the intrusion of information that could be excluded immediately on the basis that it does not satisfy a maintenance criterion. A *delayed intrusion* is the intrusion of information that cannot be excluded until later because it temporarily satisfies the updating criterion. When comparing intrusion errors of skilled and less-skilled readers, Carretti et al. found that less-skilled readers made more delayed-intrusion errors. The authors concluded that the core problem for less-skilled readers is their difficulty to control activated information in working memory.

It follows that poor updating function is associated with poor reading comprehension specifically because readers with poor updating have difficulty adjusting activation of relevant information due to the maintenance and subsequent intrusions of irrelevant information. Such intrusions are, in part, the result of an inability to inhibit the activation of irrelevant information. Thus, less-skilled readers' difficulty in avoiding intrusion errors may be related to the sheer quantity of irrelevant information in working memory that must be inhibited, and may not be associated with increased overall memory load or retrieval processes. Indeed, Palladino et al. (2001) suggested that the quantity of items that must be *inhibited* contributes to differences in performance on updating tasks, whereas the amount of information that must be *selected* (i.e., target information) does not. Thus, an increase in the amount of irrelevant, and even relevant-but-non-target information that must be excluded from working memory creates more difficulty than information that must be maintained, especially for less-skilled readers.

García-Madruga, Vila, Gómez-Veiga, Duque, and Elosúa (2014) also found that updating (measured using a word updating task based on that of Palladino et al. 2001) predicted reading comprehension processes in Spanish third-grade children. These processes included inferencing and integration of prior knowledge with information from the text during reading, measured via the Spanish version of the Diagnostic Assessment of Reading Comprehension (DARC; August, Francis, Hsu, & Snow, 2006).

Although the aforementioned investigations have indicated a clear predictive relation between updating and reading comprehension, Muijselaar and De Jong (2015) found that updating, when measured via a word updating task, did not predict reading comprehension for typically developing children. This held even after reading speed, vocabulary knowledge, and verbal short-term memory were controlled. The authors explained that their results may be due, in part, to the fact that the demands of the updating task and the updating demands of the reading comprehension measures used differed substantially. Specifically, updating during reading is far more complex than the demands imposed by an updating task. The differences in complexity lie in the selection of information to be updated during reading. For example, the information contained in updating tasks is relatively constrained compared to information in texts. Comprehending text involves a complex interaction between working memory and long-term memory, whereas updating tasks do not necessitate such an interaction. In short, because the demands of updating tasks may not necessarily reflect the updating demands of reading actual texts, the strength of the relation between updating and reading comprehension reported in the literature varies.

Further, updating during reading is thought to be influenced by both domain-general and domain-specific factors. With respect to domain-general factors, storage and processing both influence updating, although not to the same degree (Carretti et al., 2009; Daneman & Carpenter, 1980). To explain, tasks that simultaneously tap storage and processing of information predict reading comprehension more strongly than storage-only tasks. This suggests that the processing component of working memory is more critical to updating during reading comprehension than storage alone. This is consistent with the idea that effective updating during reading is not simply a matter of holding as much information as possible in working memory (Palladino et al. 2001), but a matter of continuously selecting and updating working memory contents.

With respect to domain-specific factors, there is evidence that performance on verbal span tasks can distinguish skilled and less-skilled comprehenders (Pelegrina, Capodieci, Carretti,

& Cornoldi, 2015), whereas performance on visuospatial span tasks does not (Pimperton & Nation, 2010), indicating that inhibitory deficits that constrain updating, and working memory more generally, could be specific to the verbal domain. Likewise, Pelegrina et al. found that less-skilled comprehenders performed worse on a word updating task than on a number updating task, whereas children with a math disability performed worse on a number updating task than on an object updating task. Thus, semantic and quantitative updating tasks may demand somewhat different updating processes, which supports the idea that differences in updating may, in part, be due to domain-specific factors.

Importantly, updating may not be implicated in all reading comprehension situations. For example, Potocki, Sanchez, Ecalle, and Magnan (2017) found that fifth-grade children’s performance on an *n*-back task predicted only certain components of reading comprehension. Particularly, updating predicted inferential comprehension processes, but not literal comprehension processes (e.g. simple recall). Thus, the authors suggest that EFs (particularly updating, planning, and inhibition) are implicated more heavily in complex and more “ecological” reading situations, such as foraging for information in expository texts or in online environments, and less heavily in “classical” situations of reading narrative texts.

To summarize, one of the most important conclusions from past investigations is that updating is important to reading comprehension in that readers must maintain relevant information and must exclude irrelevant information in working memory to successfully construct a coherent representation of a text. If updating is responsible for the selection and maintenance of relevant information, then it follows that a separate, yet related, mechanism is responsible for the exclusion of irrelevant information. Namely, successful updating may require the ability to inhibit irrelevant information (Carretti et al. 2005). We turn to this EF component next.

Inhibition

Across many investigations, *inhibition* has typically referred to the active suppression of dominant, automatic responses (e.g., Altemeier, Abbot, & Berninger, 2008; Kieffer et al., 2013; Miyake et al., 2000; van der Sluis, De Jong, & van der Leij, 2004). Many researchers endorse the idea that inhibition is the primary EF that supports the development of other EFs, including shifting and updating, but also higher-order skills like planning and goal-setting (e.g., Blair, Zelazo, & Greenberg, 2005; Carlson & Moses, 2001; Pennington, 1997). The term "inhibition" can be used broadly to capture several processes. For example, active inhibition is prototypical, but inhibition may also take the form of resistance to intrusions of irrelevant information from memory (i.e., proactive interference) or resistance to distracting information (Friedman & Miyake, 2004). This notion is consistent with Nigg's (2000) taxonomy of different facets of inhibitory control, as well as accumulating evidence that individual differences in inhibition-related functions are not unitary (e.g., Kane, Meier, et al., 2016; Yin & Peng, 2016).

Hasher, Zacks, and May (1999) provided an additional taxonomy of inhibitory functions. In their view, inhibition can control working memory contents via three functions: access, deletion, and restraint. Specifically, inhibition may restrict *access* to working memory only to task-relevant information, thereby not allowing task-irrelevant information to interfere in the first place. If information is in working memory but becomes irrelevant, inhibition may also *delete* the irrelevant information from the working memory buffer, allowing relevant information to dominate. Finally, inhibition may *restrain* dominant responses from seizing control and being carried out so that subordinate responses can be actively considered. Given this view, Chiappe, Seigel, and Hasher (2000) argued that the restraint function is responsible for suppressing incorrect or irrelevant interpretations of text and language.

Demagistri, Richards, and Juric (2014) argued that the three previously discussed inhibition-related functions, measured directly via the Hayling Task (Cartoceti, Sampedro, Abusamra, & Ferreres, 2009) relate to reading comprehension. The Hayling task assesses verbal initiation and suppression (Demagistri et al. 2014) by presenting participants sentences that are missing the last word (e.g., “In a baseball game, the pitcher throws the _____.”), and participants must complete with either a consistent word (initiation) or an inconsistent word (suppression). In this context, inhibition was indexed as the latency between initiation and suppression (e,g. Chiappe et al., 2000).

Demagistri et al. (2014) also measured inhibition indirectly via analysis of intrusion errors on a listening span task (Injoque-Ricle, Calero, Alloway, & Burín, 2011). Specifically, intrusions of studied, but non-target, words comprised the access function; intrusions of words from previous lists (i.e. resistance to proactive interference) comprised the deletion function in that proactive interference, as indicated by intrusion errors of targets from previous lists on the listening span task, may reflect a failure of inhibition to “delete” irrelevant information; finally, intrusions of words that did not appear in the task comprised the restraint function. Demagistri et al. found that skilled comprehenders required less time to *delete* irrelevant information and *restrain* dominant responses than less-skilled comprehenders. Moreover, older adolescents (17-18 years of age) were more skilled than younger adolescents (13-14 years of age) in accessing relevant lexical content, detaining irrelevant content, and avoiding intrusion errors when the automatic response must be suppressed in favor of a relevant, subordinate response.

Using a similar analysis, Chiappe et al. (2000) found that less-skilled readers did not differ from skilled readers in the deletion function, but they did underperform in both the access and restraint functions of inhibition. This study included a large age range (age groups: 6-9, 10-19, 20-29, 30-39, 40-49) and allowed for interesting comparisons to be made. For example, less-skilled readers showed general impairments in suppressing irrelevant information from working memory (*access*) regardless of their age group, but for skilled readers, only older adults experienced this difficulty.

By any account, inhibition may be important for reading comprehension in that it mitigates the effects of distracting, outdated, or irrelevant information (Christopher et al., 2014; Hasher et al., 1999). The findings, though, have been mixed, and researchers hypothesized that the differences may have been driven primarily by the type of inhibition function being measured and/or the developmental level of the participants. With respect to the type of inhibition function, Borella, Carretti, and Pelegrina (2010) directly compared resistance to proactive interference (measured by the PI (Proactive Interference) Task; Borella et al. 2010), prepotent response or active inhibition (measured by Hayling task; Burgess & Shallice, 1996; Animal Stroop and Color Stroop Tasks; See Table 1), and resistance to distractors inhibition (measured by TextWithDistractors; Connelly, Hasher, & Zacks, 1991) in skilled and less-skilled readers. They found that less-skilled readers tended to perform as well as skilled readers in terms of the number of items correctly recalled on the measure of resistance to proactive interference, but less-skilled readers made more intrusion errors than skilled readers. Skilled and less-skilled readers performed comparably on measures of resistance to distracting information and prepotent response inhibition. Borella et al. concluded that during reading, less-skilled readers have difficulty controlling irrelevant information at retrieval, but not at encoding. This suggests that less-skilled readers have difficulty blocking irrelevant information from being reactivated as they attempt to retrieve relevant information. Therefore, irrelevant information gets reactivated along with target relevant information. Less-skilled readers may also have difficulty suppressing already activated information (Borella et al.). Thus, one interpretation is that difficulty suppressing or inhibiting irrelevant information may be attributed to a weakness in less-skilled readers' ability to resist proactive interference, however, it is the case that not all accounts of proactive interference implicate inhibitory processes (e.g., Jonides & Nee, 2006). By any account, a poor suppression mechanism increases the likelihood for intrusion errors, which then channels resources away from relevant information. As an additional note, this interpretation is consistent with the findings of Gernsbacher and colleagues (Gernsbacher et al., 1990; Gersnbacher & Faust, 1991) that suppression/inhibition is a key factor in determining individual differences in reading skill.

With respect to the developmental level of the participants, Kieffer et al. (2013) provided evidence that prepotent response inhibition (measured via a Stroop task) may govern 9-10-year-old children's ability to employ a number of top-down processes that are necessary for comprehension, including inference making, synthesizing information, and suppressing irrelevant information. Conversely, Borella et al. (2010) found that prepotent response inhibition (measured via Stroop tasks) did not explain variance in reading comprehension in a sample of 10-11-year-old children. Likewise, Christopher et al. (2014) found that inhibition (measured via Gordon Diagnostic System vigilance and distractibility tasks (Gordon, 1983) and Stop-Signal Reaction Time task) did not relate to word reading or reading comprehension in a sample of 8-16 year olds after naming speed, working memory, and general intellectual ability were controlled. As Nouwens, Groen, and Verhoeven (2016) noted, developmental differences across samples may in part contribute to conflicting results. Specifically, performance on inhibition tasks continues to improve until adolescence (Davidson, Amso, Anderson, & Diamond, 2006), which suggests that inhibition-related functions may work differently between younger and older populations. (Kieffer et al., 2013). However, because existing studies have reported differences between samples of overlapping age groups, more research is needed to determine whether developmental differences indeed influence the relation between inhibition and reading comprehension.

As highlighted earlier, Gernsbacher (1991) demonstrated that suppression plays a role in word-level and sentence-level comprehension. For example, Gernsbacher and Faust (1991) recorded response times for target words (e.g., ACE) after reading sentences that end in homographs. In the ACE example, the experimental sentence was *He dug with a spade* and the control sentence was *He dug with a shovel.* When participants responded to the target word (spade) immediately upon its presentation, the time to reject the target word was slower if it occurred after the experimental sentence than if it occurred after the control sentence. After a 1-second delay, however, this difference disappeared, but *only* for skilled readers. Gernsbacher and Faust interpreted this finding as evidence that skilled readers suppressed the irrelevant meaning of *spade*, whereas the less-skilled readers could not do so. Although Gernsbacher and Faust found evidence that suppression moderated reading comprehension ability, they found that enhancement did not, meaning that comprehension ability did not depend on whether certain information received increased activation, but instead relied on irrelevant information decreasing in activation.

Other research has corroborated the idea that a suppression mechanism is essential to reading comprehension. De Beni and Palladino (2000) analyzed errors on forward/backward digit span and a verbal working memory task and found that less-skilled comprehenders made more intrusion errors than skilled comprehenders. This result indicates that less-skilled readers hold more irrelevant information in working memory compared to skilled comprehenders. The irrelevant information that burdens less-skilled comprehenders takes away resources that skilled comprehenders are able to use more efficiently for maintaining relevant information in working memory. Expanding on this work, Cain (2006) found that less-skilled comprehenders did not differ from skilled comprehenders on short-term memory tasks that required recalling lists of digits and concrete and abstract words. However, skilled-comprehenders performed significantly better than less-skilled comprehenders when tasks required them to supply and remember the final words to sentences or remember arrays of dots. Unsurprisingly, less-skilled comprehenders' errors suggested an inability to suppress irrelevant information.

In another study, McVay and Kane (2012) investigated the relation between working memory and reading comprehension, arguing that performance on inhibition tasks (conceptualized as attention control) partially underlies this relation. Attention control tasks included a Numerical Stroop task, Semantic SART, and an Antisaccade task. McVay and Kane found that attention control did not significantly contribute to reading comprehension, but did have a significant indirect effect via mind-wandering propensity during reading. The authors noted that executive attention may be invoked when competition resolution is necessary for comprehension, such as when readers encounter ambiguous homonyms or homographs. Importantly, the authors argued that, because attention processes contributed more than memory-based processes to variation in reading comprehension, skilled comprehenders may have less trouble suppressing the effects of mind wandering (e.g., activating task-unrelated information), whereas less-skilled comprehenders do not have the capacity to do so, which leads to more irrelevant information competing for the reader's limited attention.

To summarize, inhibition functions relate to reading comprehension by helping readers manage the activation of irrelevant information. Active inhibition of prepotent responses may enable readers to actively suppress the activation of irrelevant information from the environment or discourse situation to prevent it from interfering with comprehension. Resistance to proactive interference may prevent irrelevant information activated in memory from intruding during reading comprehension. Together, these functions allow more activation to support relevant information and prevent the working memory system from becoming overburdened with irrelevant information.

Shifting

Compared to updating and inhibition, there has been relatively little research on the relation between shifting functions and reading comprehension. What little evidence exists is mixed—a few studies have reported a contribution of shifting to reading comprehension (e.g. Van der Sluis, de Jong, and van der Leij, 2007; Yeniad, Malda, Mesman, van IJzendoorn, & Pieper, 2013), whereas others have failed to identify that connection (e.g. McLean & Hitch, 1999). Generally, shifting refers to the ability to switch between multiple tasks, operations, and mental sets (Monsell, 1996). Shifting has also been referred to as "attention switching" and "task switching," and more loosely as "cognitive flexibility." In addition, shifting has been implicated in attention control models (Norman & Shallice, 1986).

There are several ways in which shifting and cognitive flexibility ability may relate to reading comprehension. For example, comprehension relies on the orchestration of multiple attention-control processes, such as attending to phonological, syntactic, and semantic features, while also employing different strategies and metacognitive practices (Cartwright, 2008; Pressley & Afflerbach, 1995). More recently, it has been documented that the ability to shift attention between or flexibly consider semantic and phonological features of printed text contributes significant unique variance to comprehension over and above the independent contributions of phonological and semantic processing, even when general cognitive ability and age differences are controlled (Cartwright, 2007; Cartwright, Hodgekiss, & Isaac, 2008). This flexibility, termed *graphophonological-semantic flexibility,* is a significant predictor of performance on different measures of reading comprehension for beginning readers, intermediate-level readers, and adults (Cartwright, 2008, 2015; Guajardo & Cartwright, 2016).

Specifically, Guajardo and Cartwright (2016) assessed graphophonological-semantic flexibility with a classification task in which children sort words by different criteria regarding the words' sound and/or meaning, and general flexibility skill with a classification task in which children sort pictures according to color and/or type of object. They found that both general flexibility and graphophonological-semantic flexibility, indexed as the number of errors and speed of classification, accounted for unique variance in reading comprehension (13.9% and 9.1%, respectively). The authors concluded that cognitive flexibility supports comprehension by allowing readers to consider multiple aspects of the text simultaneously (Cartwright, 2015; Guajardo & Cartwright, 2016). By contrast, cognitive *inflexibility* or shifting deficits (Zelazo & Frye, 1998) can be detrimental to comprehension processes. For example, an inability to shift from focusing on word-level processing precludes readers from grasping the overall meaning of a text (Cartwright, 2006).

Although the aforementioned research has indicated that shifting/cognitive flexibility relates to reading comprehension, the mechanisms by which it operates remain unclear

(Cartwright, 2008). It may be that shifting mediates the relation between vocabulary knowledge and reading comprehension. Specifically, if a reader maintains an inflexible focus on phonological features of a text at the expense of attending to semantic information, then access to existing semantic knowledge that underlies comprehension will also be limited. Indeed, Cartwright, Marshall, Dandy, and Isaac (2010) found that cognitive flexibility (measured via a color-shape card sorting task, see Table 1) mediated the relation between vocabulary and comprehension for first-grade and second-grade children. Vocabulary alone did not predict comprehension so long as children had strong shifting skills, but students who were ‘less flexible’ struggled with comprehension—a pattern that held up when the same children were tested two years later.

There have been other tentative explanations for the relation between shifting and reading comprehension. For example, Kieffer et al. (2013) hypothesized that shifting may be involved in higher-level reading processes. Kieffer et al measured shifting using the Wisconsin Card Sort Task (Kongs, Thompson, Iverson, & Heaton, 2000), which requires participants to deduce changing card sorting criteria from trial feedback. Kieffer et al. found that shifting, indexed as the number of perseverative errors in sorting, contributed directly to reading comprehension (measured via Gates-MacGinitie Reading Comprehension Test, MacGinitie, MacGinitie, Maria, & Dreyer, 2000), as well as indirectly via language comprehension (measured via Woodcock Johnson III battery, Woodcock, McGrew, & Mather, 1999). Likewise, Fuhs, Nesbitt, Farran, and Dong (2014) found that a composite EF score derived from six measures was related to language comprehension (measured via the Oral Comprehension subscale on the Woodcock-Johnson III; Woodcock, McGrew, & Mather, 2001) in kindergarteners. These findings taken together suggest that shifting, and perhaps EF more generally, could be implicated in real-time oral language processing, as well as in the development of higher-level oral language skills. Language comprehension requires the coordination of bottom-up (i.e., vocabulary and syntax) and top-down (i.e., pragmatic) information with general world knowledge (Kendeou et al., 2016). Appropriate use of this information likely places heavy demands on attention shifting skills. Kieffer et al. pointed out that one avenue through which shifting could influence language comprehension is in the ability to suppress perseveration in the face of syntactic or semantic ambiguities during online language processing.

Shifting may also be involved in lower-level reading processes. Altemeier et al. (2008) found that rapid automatic switching (see Table 1), a measure that relies heavily on shifting, only weakly predicted future reading comprehension ability in first-grade and third-grade children. The authors posited that rapid automatic switching may have contributed more so to lower-level skills such as word reading than to comprehension. The authors explained that inferences, predictions, grasping important ideas, and metacognition may require higher-level executive functions like planning, which relies on an orchestration of lower-level EF components. In this view, shifting supports reading moment-by-moment at a lower level by linking letters to sounds.

It is important to note that the relation between shifting and reading is influenced by shifting's relation with updating. Specifically, Potocki et al. (2017) found that the contribution of children's shifting abilities (measured via an animal sorting task) to reading comprehension was conditional based on whether the working memory task used placed heavy demands on updating. The authors included performance on an *n*-back task in their analyses and found no significant contribution of shifting to reading comprehension. The authors explained that shifting ability is closely associated with updating ability, so including both updating and shifting tasks might partly mask the association between shifting and reading comprehension. Indeed, when they used a working memory task that did not rely on updating ability (i.e., the letter-number sequencing subtest from the fourth edition *Weschler Intelligence Scale for Children*) they found that shifting significantly predicted children's reading comprehension.

To summarize, there is limited evidence to support the relation of shifting functions to reading comprehension. However, the findings of the few studies that have been conducted suggest that shifting may support readers' ability to effectively engage in lower-level reading abilities, such as flexibly considering phonological and semantic information during reading, shifting between reading strategies, monitoring one's comprehension, and engaging in metacognitive processes. Overall, more work is needed to specify the ways in which shifting relates to reading comprehension abilities.

Conclusions and Future Directions

Our aim in this paper was to understand the extent to which, and under what conditions, the different components of EF (i.e., updating working memory, inhibition, and shifting/cognitive flexibility) relate to reading comprehension. Several important conclusions have been drawn. First, we identified empirical evidence that these EF components are important for reading comprehension. Specifically, (a) updating supports readers' comprehension by maintaining the activation of relevant information in working memory during reading; (b) inhibition supports comprehension by suppressing the activation of irrelevant text information and preventing the intrusion of irrelevant information from memory; and, (c) shifting supports comprehension by integrating semantic and phonological information during reading, and by flexibly allocating attention to features of the text and reading strategies. Second, the review also revealed that, despite the evidence for the important role of EFs in reading comprehension, prominent process models of reading comprehension have, for the most part, not explicitly incorporated EFs.

The review has also identified several important, yet unresolved, issues regarding the role EFs play in reading comprehension. One issue pertains to our understanding of *how* the relations and interdependencies amongst the EF components support reading comprehension. For example, updating abilities enable readers to maintain the activation of relevant information during reading. However, this depends, in part, on inhibition functions since inhibition enables readers to suppress irrelevant information. Although there is evidence for independent contributions for updating and inhibition, the interdependencies of these two components in the context of reading are not well understood. Additionally, shifting has been found to support reading-related abilities, but its contribution depends on whether updating is also included in the equation. Because EF components are interrelated and interdependent, further research is needed to understand how each function contributes uniquely and in relation to each other.

Pertinent to future investigations of EF and reading comprehension, it is important to consider the executive demands of the task used to measure reading comprehension (Potocki et al., 2017). For example, Cutting et al. (2009) showed that a composite EF score, which included planning and organization in addition to lower-level EFs, uniquely accounted for significant variance in reading comprehension when reading was measured with the Gray Oral Reading Test-Fourth Edition (GORT-4, Wiederholt & Bryant, 2000) but not when reading was measured with the Woodcock Reading Mastery Test-Revised (WRMT-R; Woodcock, 1998). As Cutting et al. explained, this suggests that some reading comprehension measures may tap into EFs to differing degrees. Additionally, Eason, Goldberg, Young, Geist, and Cutting (2012) found that EF (primarily planning and organizing functions) predicted expository text comprehension and inferential question accuracy, but not narrative text comprehension in children with and children without reading disabilities, suggesting that text genre is another factor that also needs to be considered.

Another issue pertains to the measurement of EFs. As we discussed above, oftentimes, single measures are used to assess EFs despite the important differences and roles of different EF components. Related, each of these EFs also has different dimensions that need to be considered (Potocki et al., 2017). For example, inhibition is not a unitary construct, nor is shifting, and different tasks have been shown to differentially tap into these abilities. Additionally, researchers should be mindful of the tasks they select to measure EFs, as some tasks may be better in some contexts than in others. For example, choosing an EF task that relies heavily on lexical skills may be problematic because lexical skills may influence performance on both the EF task and reading comprehension.

Importantly, the evidence from this review for the relation of different EFs and reading comprehension suggests that EFs have a place in a comprehensive theory of reading comprehension because they can help account for individual differences in how readers process and interact with different texts. For example, in the Structure Building Framework (Gernsbacher, 1991), the suppression mechanism, which allows readers to suppress the activation of irrelevant information, is directly responsible for individual differences in reading comprehension processes, such as inference making. The addition of EFs may also help account for developmental differences. For example, in the Event Indexing model (Zwaan et al., 1995), shifting, which may allow readers to flexibly shift attention to different dimensions during reading (e.g., causal, spatial, and so on), is responsible for developmental differences observed between children and adults (Bohn-Gettler et al., 2011). Regarding developmental differences, more work is needed to understand the role of EF, which is often conceptualized as an undifferentiated construct in childhood, in the development in literacy skills (Cutting et al., 2009; Zelazo, Blair, & Willoughby, 2016).

The addition of EFs in current models of reading comprehension may also help account for substantial unaccounted variance in comprehension performance. For instance, Conners (2008) argued that monitoring reading processes, interrupting processes when a problem occurs, and adopting alternative processes when one process fails are essential to reading comprehension. These processes may be analogous to the three EF components. Namely, monitoring reading processes may involve updating working memory, interrupting processes may involve inhibition, and adopting alternative processes may rely on shifting. Importantly, these processes, which fall under the term *attentional control,* may contribute to the interaction of core reading components—decoding and language comprehension (Simple View of Reading-SVR; Hoover & Gough, 1990). Indeed, Cutting and colleagues (Aboud, Bailey, Petrill, & Cutting, 2016; Cutting, Bailey, Barquero, & Aboud, 2015) argued that EF may be important for successfully orchestrating the development and interaction of decoding and language comprehension, and a better understanding of the role of EF in reading comprehension for various populations and reading situations may provide insight into the origins of success or failure in reading comprehension (e.g. Cutting et al., 2009; Fuhs et al., 2014).

Although this review focused on only three EF components, it is important to also understand how higher-level EFs, such as planning, also relate to reading comprehension. For example, planning—formulating a course of action and carrying it out with organization, strategy, and efficiency (Best, Miller, & Jones, 2009)—has been shown to contribute unique variance to reading comprehension (Cutting et al., 2009; Georgiou & Das, 2016; Locascio, Mahone, Eason, & Cutting, 2010; Sesma et al., 2009). Also, Kendeou, Papadopoulos, and

Spanoudis (2015) suggested that planning is necessary for coordinating higher-level processes during reading, such as shifting attention to different parts of a text and allocating resources to specific information. This idea is consistent with the view that planning is a higher-order executive function, under which lower-level EFs (i.e., shifting, updating, and inhibition) operate (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Wiebe, Espy, & Charak, 2008).

We contend that the consideration of the role of EFs in theories and models of reading comprehension is in perfect sync with recent calls in the literature for a focus on higher-level processes (Kendeou et al., 2016; McNamara, Jacovina, & Allen, 2015) that support deeper comprehension (Graesser, 2015) and thus deep learning (Goldman & Pellegrino, 2015). Inevitably, this also means moving towards greater specification and approximation of *strategic processing* in existing reading comprehension models, as it is often necessary for deeper comprehension to occur (Graesser, 2007). As this review has suggested, the need for refined reading comprehension models is great. Most models have been proposed in the 1980s, and despite advances in the discourse comprehension literature, these models have not been refined and/or further developed. Considering EFs in this context may provide information on how individual differences emerge in the fundamental processes of comprehension and how these processes interact with different reading situations to facilitate deeper comprehension and learning.

For example, one reading situation in which individual differences in EFs may become relevant is when readers experience interference between information in the text and their prior knowledge. This interference may be because the text presents inaccurate information (Rapp, 2016) or because the readers possess inaccurate information (Kendeou & van den Broek, 2005). In a recent study, Butterfuss and Kendeou (2016) explored the role of inhibition functions in the latter case. Specifically, participants with identified misconceptions read texts that refuted and explained these misconceptions (i.e., refutation texts) or control texts. The findings showed that inhibition (measured by the Stroop task) did not play a role when reading refutation texts, perhaps because refutation texts provided a causal explanation that has been shown to effectively reduce and/or eliminate interference due to misconceptions (Kendeou, Smith, & O'Brien, 2013; Kendeou, Walsh, Smith, & O'Brien, 2014). However, in the control texts, differences emerged among readers with varying levels of active inhibition ability. These differences suggested that readers likely experienced different levels of interference depending on their ability to inhibit irrelevant information. Future work will need to unpack these findings to understand better how EF components influence reading behavior across a host of different domains and reading situations, including texts that contain conflicting information and texts that lack cohesion. This is especially timely in the era of 'fake news,' misinformation, and the general public's wavering endorsement of scientific evidence and reliance on misleading claims.

Concluding Remarks

Our aim in this paper was to understand the extent to which, and under what conditions, the core components of EF (i.e., updating, inhibition, and shifting) play a role in reading comprehension. The review revealed evidence for the important role of EFs in reading comprehension, specifically in the activation and suppression of information during reading. Despite this evidence, prominent models of reading comprehension have not explicitly incorporated EFs. Thus, there is a need for existing models of reading comprehension to incorporate and account for the role of EFs, as EFs can help explain the mechanisms of complex interactions between the reader, the text, and the greater discourse situation.

References

*Aboud, K., Bailey, S., Petrill, S., & Cutting, L.E. (2016). Comprehending text versus reading words in young readers with varying reading ability: Distinct patterns of functional connectivity from common processing hubs. *Developmental Science,* 632-656. doi:10.1111/desc.12422

Albrecht, J. E., & O'Brien, E. J. (1993). Updating a mental model: Maintaining both local and global coherence. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 1061-1070. http://dx.doi.org/10.1037/0278-7393.19.5.1061

*Altemeier, L. E., Abbott, R. D., & Berninger, V. W. (2008). Executive functions for reading and writing in typical literacy development and dyslexia. *Journal of Clinical and Experimental Neuropsychology, 30,* 588-606. http://dx.doi.org/10.1080/13803390701562818

August, D., Francis, D. J., Hsu, H. A., & Snow, C. E. (2006). Assessing reading comprehension in bilinguals. The Elementary School Journal, 107(2), 221–238. doi:10.1086/510656.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology: Section A, 49,* 5-28. doi:http://dx.doi.org/10.1080/713755608

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4,* 417-423. http://dx.doi.org/10.1016/S1364-6613(00)01538-2

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience, 4*, 829-839. Doi:10.1038/nrn1201

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

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation, 8,* 47-89. http://dx.doi.org/10.1016/S0079-7421(08)60452-1

Baddeley, A. D. (1998). Random generation and the executive control of working memory. *Quarterly Journal of Experimental Psychology, 51(A),* 819–852.

Barnes, M.A. (2016). What do models of reading comprehension and its development have to contribute to a science of comprehension practice and assessment for adolescent students? In K. Santi & D. Reed (Eds.), *Improving comprehension for middle and high school students*. Springer.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29,* 180-200. http://dx.doi.org/10.1016/j.dr.2009.05.002

Blair, C., Zelazo, P. D., & Greenberg, M. T. (2005). The measurement of executive function in early childhood. *Developmental Neuropsychology, 28,* 561-571. http://dx.doi.org/10.1207/s15326942dn2802_1

Bohn-Gettler, C., Rapp, D., van den Broek, P., Kendeou, P., & White, M. (2011). Adult's and children's monitoring of story events in the service of comprehension. *Memory & Cognition, 39*, 992- 1011. doi: https://doi.org/10.3758/s13421-011-0085-0

*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(6),* 541-552. doi:10.1177/0022219410371676

Budd, D., Whitney, P., & Turley, K. J. (1995). Individual differences in working memory strategies for reading expository text. *Memory & Cognition, 23,* 735-748. Doi: 10.3758/BF03200926

Burgess, P. W., & Shallice, T. (1996). Bizarre responses, rule detection and frontal lobe lesions. *Cortex*, *32*(2), 241-259.

Butterfuss, R., & Kendeou, P. (2016, July). *The role of executive function in knowledge revision*. Paper presented at the Society of Text and Discourse Annual Conference, Kassel, Germany.

Cain, K. (2006). Individual differences in children's memory and reading comprehension: An investigation of semantic and inhibitory deficits. *Memory, 14*(5), 553-569. http://dx.doi.org/10.1080/09658210600624481

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,* 31-43. http://dx.doi.org/10.1037/0022-0663.96.1.31

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72,* 1032-1053. Doi:10.1111/1467-8624.00333

*Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences, 19,* 246-251. http://dx.doi.org/10.1016/j.lindif.2008.10.002

*Carretti, B., Cornoldi, C., De Beni, R., & Palladino, P. (2004). What happens to information to be suppressed in working-memory tasks? Short and long term effects. *The Quarterly Journal of Experimental Psychology Section A*, *57*(6), 1059-1084. http://dx.doi.org/10.1080/02724980343000684

*Carretti, B., Cornoldi, C., De Beni, R., & Romanò, M. (2005). Updating in working memory: A comparison of good and poor comprehenders. *Journal of Experimental Child Psychology, 91,* 45-66. http://dx.doi.org/10.1016/j.jecp.2005.01.005

*Cartoceti, R., Sampedro, B., Abusamra, V., & Ferreres, A. (2009). Evaluacion de la iniciación y supresión de respuesta verbal en niños. *Revista Fonoaudiologica*, *52*(2), 9-24.

*Cartwright, K. B. (2006). Fostering flexibility and comprehension in elementary students. *The Reading Teacher, 59*(7), 628-634. Doi:10.1598/RT.59.7.2

*Cartwright, K. B. (2007). The contribution of graphophonological-semantic flexibility to reading comprehension in college students: Implications for a less simple view of reading. *Journal of Literacy Research, 39,* 173–193. Doi:10.1080/10862960701331902

*Cartwright, K. B. (2008). Cognitive flexibility and reading comprehension. In C.C. Block & S. R. Parris (Eds.), *Comprehension instruction: Research-based best practices* (pp. 50-64). New York: Guilford.

*Cartwright, K. B. (2015). Executive function and reading comprehension: The critical role of cognitive flexibility. In S. R. Parris & K. Headley (Eds.), *Comprehension instruction: Research-based best practices* (3rd ed., pp. 56–71). New York: Guilford.

*Cartwright, K., Hodgekiss, M. D., & Isaac, M. C. (2008). Graphophonological-semantic flexibility: Contributions to skilled reading across the lifespan. In K. B. Cartwright (Ed.), *Literacy processes: Cognitive flexibility in learning and teaching.* New York: Guilford.

*Cartwright, K. B., Marshall, T. R., Dandy, K. L., & Isaac, M. C. (2010). The development of graphophonological-semantic cognitive flexibility and its contribution to reading comprehension in beginning readers. *Journal of Cognition and Development*, *11*(1), 61-85. doi:http://dx.doi.org/10.1080/15248370903453584

*Chiappe, P., Siegel, L. S., & Hasher, L. (2000). Working memory, inhibitory control, and reading disability. *Memory & Cognition*, *28*(1), 8-17. doi: https://doi.org/10.3758/BF03211570

*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*(3), 470-488. doi:10.1037/a0027375

Cohen, J. D., Perlstein, W. M., Braver, T. S., Nystrom, L. E., Noll, D. C., Jonides, J., & Smith, E. E. (1997). Temporal dynamics of brain activation during a working memory task. *Nature, 386* (6625), 604-608. doi:http://dx.doi.org/10.1038/386604a0

Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6,* 533–541. http://dx.doi.org/10.1037/0882-7974.6.4.533

*Conners, F. A. (2009). Attentional control and the simple view of reading. *Reading and Writing*, *22*(5), 591-613. doi:10.1007/s11145-008-9126-x

*Cutting, L.E., Bailey, S.K., Barquero, L.A., & Aboud, K. (2015). Neurobiological bases of word recognition and reading comprehension. In C.M. Connor & P. McCardle (Eds.), *Advances in reading intervention: Research to practice to research* (pp. 73–84). Baltimore, MD: Brookes Publishing.

*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. doi:10.1007/s11881-009-0022-0

*Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 450-466. doi:http://dx.doi.org/10.1016/S0022-5371(80)90312-6

Daneman, M., & Carpenter, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*(4), 561-584. doi:http://dx.doi.org/10.1037/0278-7393.9.4.561

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review, 3*(4), 422-433. doi:10.3758/BF03214546

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994). *Assessment of cognitive processes: The PASS theory of intelligence*. Boston, MA: Allyn & Bacon

Davelaar, E. J., Goshen-Gottstein, Y., Ashkenazi, A., Haarmann, H. J., & Usher, M. (2005). The demise of short-term memory revisited: empirical and computational investigations of recency effects. *Psychological Review, 112,* 3-42. doi:http://dx.doi.org/10.1037/0033-295X.112.1.3

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037-2078. doi: 10.1016/j.neuropsychologia.2006.02.006

*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. doi:http://dx.doi.org/10.1016/S1041-6080(01)00033-4

Denckla, M. B. (1996). A theory and model of executive function: A neuropsychological perspective. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 263–278). Baltimore: Brookes.

*Demagistri, M. S., Richards, M. M., & Juric, L. C. (2014). Incidencia del funcionamiento ejecutivo en el rendimiento en comprensión lectora en behaviorits. *Electronic Journal of Research in Educational Psychology*, *12*(33), 1-27.

*Eason, S. H., Goldberg, L. F., Young, K. M., Geist, M. C., & Cutting, L. E. (2012). Reader–text interactions: How differential text and question types influence cognitive skills needed for reading comprehension. *Journal of Educational Psychology*, *104*(3), 515-528. doi:10.1037/a0027182

Fisk, J. E., & Sharp, C. A. (2004). Age-related impairment in executive functioning: Updating, inhibition, shifting, and access. *Journal of Clinical and Experimental Neuropsychology, 26*(7), 874-890. doi:http://dx.doi.org/10.1080/13803390490510680

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of Experimental Psychology: General, 133*(1), 101-135. doi:http://dx.doi.org/10.1037/0096-3445.133.1.101

*Fuhs, M. W., Nesbitt, K. T., Farran, D. C., & Dong, N. (2014, April 21). Longitudinal Associations Between Executive Functioning and Academic Skills Across Content Areas. Developmental Psychology. Advance online publication. doi:http://dx.doi.org/10.1037/a0036633

*García-Madruga, J. A., Vila, J. O., Gómez-Veiga, I., Duque, G., & Elosúa, M. R. (2014). Executive processes, reading comprehension and academic achievement in 3th grade primary students. *Learning and individual differences*, *35*, 41-48. doi: https://doi.org/10.1016/j.lindif.2014.07.013

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychological Bulletin, 134*, 31-60. doi:10.1037/0033-2909.134.1.31

*Georgiou, G. K., & Das, J. P. (2016). What component of executive functions contributes to normal and impaired reading comprehension in young adults? *Research in Developmental Disabilities, 49*, 118-128. doi:http://dx.doi.org/10.1016/j.ridd.2015.12.001

Gernsbacher, M. A. (1991). Cognitive processes and mechanisms in language comprehension: The structure building framework. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 217–263). New York: Academic Press.

*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. doi:http://dx.doi.org/10.1037/0278-7393.17.2.245

*Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 16,* 430–445. doi:http://dx.doi.org/10.1037/0278-7393.16.3.430

Goldman, S. R., & Pellegrino, J. W. (2015). Research on learning and instruction: Implications for curriculum, instruction, and assessment. *Policy Insights from the Behavioral and Brain Sciences*, *2*(1), 33-41. doi: 10.1177/2372732215601866

Gordon, M. (1983). *The Gordon Diagnostic System.* DeWitt, NY: Gordon Systems.

Graesser, A. C. (2007). An introduction to strategic reading comprehension. In D. S. McNamara (Ed.), *Reading comprehension strategies: Theories, interventions, and technologies.* New York: Erlbaum.

Graesser, A. C. (2015). Deeper learning with advances in discourse science and technology. *Policy Insights from the Behavioral and Brain Sciences, 2*(1), 42-50. doi: 10.1177/2372732215600888

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101,* 371-395.

*Guajardo, N. R., & Cartwright, K. B. (2016). The contribution of theory of mind, counterfactual reasoning, and executive function to pre-readers' language comprehension and later reading awareness and comprehension in elementary school. *Journal of Experimental Child Psychology, 144,* 27-45. doi:http://dx.doi.org/10.1016/j.jecp.2015.11.004

Hannon, B., & Daneman, M. (2001). A new tool for measuring and understanding individual differences in the component processes of reading comprehension. *Journal of Educational Psychology, 93,* 103-128. doi:http://dx.doi.org/10.1037/0022-0663.93.1.103

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention and performance. Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application* (pp. 653-675). Cambridge, MA: The MIT Press.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing, 2*(2), 127-160. doi:10.1007/BF00401799

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44*(11), 2017-2036. doi:http://dx.doi.org/10.1016/j.neuropsychologia.2006.01.010

Injoque-Ricle, I., Calero, A.D. Alloway, T.P., & Burín, D.I. (2011). Assesing working memory in Spanish-speaking children: Automated Working Memory Assessment battery adaptation. *Learning and Individual Differences, 21*, 78-84. doi:10.5872/psiencia/7.3.22

Jonides, J., & Nee, D. E. (2006). Brain mechanisms of proactive interference in working memory. *Neuroscience*, *139*(1), 181-193. doi:10.1016/j.neuroscience.2005.06.042

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*(1), 122-149. doi:http://dx.doi.org/10.1037/0033-295X.99.1.122

Kane, M. J., Conway, A. R., Miura, T. K., & Colflesh, G. J. (2007). Working memory, attention control, and the N-back task: A question of construct validity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*, 615-622. doi:http://dx.doi.org/10.1037/0278-7393.33.3.615

Kane, M. J., Meier, M. E., Smeekens, B. A., Gross, G. M., Chun, C. A., Silvia, P. J., Kwapil, T. R. (2016). Individual differences in the executive control of attention, memory, and thought, and their associations with schizotypy. *Journal of Experimental Psychology: General*, *145*(8), 1017-1048. doi:http://dx.doi.org/10.1037/xge0000184

Kendeou, P., *Smith, E. R., & O'Brien, E. J. (2013). Updating during reading comprehension: Why causality matters. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 39,* 854-865. doi:http://dx.doi.org/10.1037/a0029468

Kendeou, P., & O'Brien, E. J. (in press). Theories of text processing: A view from the top-down. In M. Schober, D. N. Rapp, & M. A. Britt (Eds.). *Handbook of discourse processes* (2nd edition). New York: Routledge.

Kendeou, P., McMaster, K. L., & Christ, T. J. (2016). Reading comprehension: Core components and processes. *Policy Insights from the Behavioral and Brain Sciences, 3*, 62-69. doi:10.1177/2372732215624707

Kendeou, P., Papadopoulos, T. C., & Spanoudis, G. (2015). Reading comprehension and PASS theory. In T. C. Papadopoulos, R. Parrila, & J. R. Kirby (Eds.), *Cognition, intelligence, and achievement* (pp. 117-136).

Kendeou, P., & van den Broek, P. (2005). The effects of readers' misconceptions on comprehension of scientific text. *Journal of Educational Psychology, 97,* 235-245. doi: 10.1037/0022-0663.97.2.235

Kendeou, P., Walsh, E., Smith, E. R., & O'Brien, E. J. (2014). Knowledge revision processes in refutation texts. *Discourse Processes, 51*, 374-397. doi: 10.1080/0163853X.2014.913961

*Kieffer, M. J., Vukovic, R. K., & Berry, D. (2013). Roles of attention shifting and inhibitory control in fourth-grade reading comprehension. *Reading Research Quarterly, 48*(4), 333-348. doi:10.1002/rrq.54

Kintsch, W. (1988). The role of knowledge in discourse comprehension: a construction-integration model. *Psychological Review, 95*(2), 163-182. doi:http://dx.doi.org/10.1037/0033-295X.95.2.163

Kintsch, W. (1998). *Comprehension: A paradigm for cognition.* Cambridge university press.

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*(5), 363-394. doi:http://dx.doi.org/10.1037/0033-295X.85.5.363

Kongs, S. K., Thompson, L. L., Iverson, G. L., & Heaton, R. K. (2000). Wisconsin card sorting test-64 card version: professional manual. *Odessa, FL: Psychological Assessment Resources*.

Larson, G. E., Merritt, C. R., & Williams, S. E. (1988). Information processing and intelligence: Some implications of task complexity. *Intelligence*, *12*(2), 131-147. doi:http://dx.doi.org/10.1016/0160-2896(88)90012-8

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*(1), 59-80. doi:10.1348/026151003321164627

*Locascio, G., Mahone, E. M., Eason, S., & Cutting, L. (2010). Executive dysfunction among children with reading comprehension deficits. *Journal of Learning Disabilities, 43,* 441-454. doi:10.1177/0022219409355476

Logan, G. D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.

MacGinitie, W. H., MacGinitie, R. K., & Maria, K. (81). K., & Dreyer, LG (2000). *Gates-MacGinitie reading tests, fourth edition. Itasica, IL: Riverside Publishing*.

McClelland, J. L., & Rumelhart, D. E. (1985). Distributed memory and the representation of general and specific information. *Journal of Experimental Psychology: General*, *114*(2), 159-188. doi:http://dx.doi.org/10.1037/0096-3445.114.2.159

McLean, J. F., & Hitch, G. J. (1999). Working memory impairments in children with specific arithmetic learning difficulties. *Journal of Experimental Child Psychology*, *74*(3), 240-260. doi: jecp.1999.2516

McNamara, D. S., & Magliano, J. (2009). Toward a comprehensive model of comprehension. *Psychology of Learning and Motivation*, *51*, 297-384. doi:http://dx.doi.org/10.1016/S0079-7421(09)51009-2

McNamara, D. S., Jacovina, M. E., & Allen, L. K. (2015). Higher order thinking in comprehension. In P. Afflerbach (Ed.), *Handbook of individual differences in reading: Text and context*, (pp. 164-176). New York: Routledge.

McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General*, *141*(2), 302-320. doi: 10.1037/a0025250

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions four general conclusions. *Current Directions in Psychological Science, 21*, 8-14. doi:10.1177/0963721411429458

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*(1), 49-100. doi:http://dx.doi.org/10.1006/cogp.1999.0734

Monsell, S. (1996). Control of mental processes. In V. Bruce (Ed.), *Unsolved mysteries of the mind: Tutorial essays in cognition* (pp. 93–148). Hove, UK: Erlbaum.

Morris, N., & Jones, D. M. (1990). Memory updating in working memory: The role of the central executive. *British Journal of Psychology, 81,* 111–121. doi:10.1111/j.2044-8295.1990.tb02349.x

*Muijselaar, M. M., & de Jong, P. F. (2015). The effects of updating ability and knowledge of reading strategies on reading comprehension. *Learning and Individual Differences*, *43*, 111-117. doi:http://dx.doi.org/10.1016/j.lindif.2015.08.011

Myers, J. L., & O'Brien, E. J. (1998). Accessing the discourse representation during reading. *Discourse processes*, *26*, 131-157. doi:http://dx.doi.org/10.1080/01638539809545042

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9,* 353–383. http://dx.doi.org/10.1016/0010-0285(77)90012-3

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin*, *126*(2), 220-246. doi:10.1037/0033-2909.126.2.220

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 4, pp. 1–18). New York: Plenum Press.

*Nouwens, S., Groen, M. A., & Verhoeven, L. (2016). How storage and executive functions contribute to children's reading comprehension. *Learning and Individual Differences*, *47*, 96-102. doi:http://dx.doi.org/10.1016/j.lindif.2015.12.008

*O'Brien, E. J., Albrecht, J. E., Hakala, C. M., & Rizzella, M. L. (1995). Activation and suppression of antecedents during reinstatement. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(3), 626-634. doi:0278-7393/95/

*Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory & Cognition*, *29*, 344-354. doi:10.3758/BF03194929

*Pelegrina, S., Capodieci, A., Carretti, B., & Cornoldi, C. (2014). Magnitude representation and working memory updating in children with arithmetic and reading comprehension disabilities. *Journal of Learning Disabilities, 48,* 658-668. doi:http://dx.doi.org/10.1177/0022219414527480.

Pennington, B. F. (1997). Dimensions of executive functions in normal and abnormal development. In G. R. Lyon & N. A. Krasnegor (Eds.), *Development of the prefrontal cortex: Evolution, neurobiology, and behavior* (pp. 265-281). Baltimore, MD: Paul H. Brookes.

*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*(4), 380-391. doi:http://dx.doi.org/10.1016/j.jml.2010.02.005

*Potocki, A., Sanchez, M., Ecalle, J., & Magnan, A. (2017). Linguistic and cognitive profiles of 8-to 15-year-old children with specific reading comprehension difficulties: The role of executive functions. *Journal of Learning Disabilities*, *50*(2), 128-142. doi: 10.1177/0022219415613080

Pressley, M., & Afflerbach, P. (1995). *Verbal protocols of reading: The nature of constructively responsive reading*. Hillsdale, NJ: Erlbaum.

*Radvansky, G. A., & Copeland, D. E. (2001). Working memory and situation model updating. *Memory & Cognition, 29*, 1073–1080. doi:10.3758/BF03206375

Rapp, D. N. (2016). The consequences of reading inaccurate information. *Current Directions in Psychological Science*, *25*(4), 281-285. doi:10.1177/0963721416649347

Redick, T. S., & Lindsey, D. R. (2013). Complex span and n-back measures of working memory: a meta-analysis. *Psychonomic Bulletin & Review*, *20*(6), 1102-1113. doi: 10.3758/s13423-013-0453-9

Roberts, R. J., Hager, L. D., & Heron, C. (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology: General, 123*, 374–393. doi:http://dx.doi.org/10.1037/0096-3445.123.4.374

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, *124*(2), 207-231. doi:http://dx.doi.org/10.1037/0096-3445.124.2.207

*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*(3), 365-385. doi:10.1348/000712605X81370

Schmiedek, F., Hildebrandt, A., Lövdén, M., Wilhelm, O., & Lindenberger, U. (2009). Complex span versus updating tasks of working memory: the gap is not that deep. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(4), 1089-1096. doi:http://dx.doi.org/10.1037/a0015730

*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*(3), 232-246. doi:http://dx.doi.org/10.1080/09297040802220029

Spector, A., & Biederman, I. (1976). Mental set and mental shift revisited. *The American Journal of Psychology*, 669-679. doi:10.2307/1421465

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643-662. doi:http://dx.doi.org/10.1037/h0054651

*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. doi:http://dx.doi.org/10.1006/jecp.1998.2477

Swanson, H. L., Howard, C. B., & Saez, L. (2006). Do different components of working memory underlie different subgroups of reading disabilities? *Journal of Learning Disabilities*, *39*(3), 252-269. doi:10.1177/00222194060390030501

Trabasso, T., Van den Broek, P., & Suh, S. Y. (1989). Logical necessity and transitivity of causal relations in stories. *Discourse Processes*, *12*(1), 1-25. doi:http://dx.doi.org/10.1080/01638538909544717

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language*, *28*, 127-154. doi:http://dx.doi.org/10.1016/0749-596X(89)90040-5

van den Broek, P., Young, M., Tzeng, Y., & Linderholm, T. (1999). The landscape model of reading. In H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 71-98). Mahwah, NJ: Erlbaum.

*Van der Sluis, S., de Jong, P. F., & van der Leij, A. (2004). Inhibition and shifting in children with learning deficits in arithmetic and reading. *Journal of Experimental Child Psychology*, *87*(3), 239-266. doi:http://dx.doi.org/10.1016/j.jecp.2003.12.002

*van der Sluis, S., de Jong, P. F., & van der Leij, A. (2007). Executive functioning in children, and its relations with reasoning, reading, and arithmetic. *Intelligence*, *35*(5), 427-449. doi:https://doi.org/10.1016/j.intell.2006.09.001

*Waters, G. S. (1996). The measurement of verbal working memory capacity and its relation to reading comprehension. *The Quarterly Journal of Experimental Psychology: Section A*, *49*(1), 51-79. doi:http://dx.doi.org/10.1080/713755607

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology*, *44*(2), 575-587. doi:http://dx.doi.org/10.1037/0012-1649.44.2.575

Wiederholt, J. L., Bryant, B. R., & Test-Revised, G. O. R. (2000). Pro-Ed. *Austin, Texas*.

Woodcock, R. W. (1998). Woodcock reading mastery tests—Revised/normative update. Circle Pines, MN: American Guidance Service.

Woodcock, R.W., McGrew, K.S., & Mather, N. (1999). *Woodcock– Johnson III Tests of Achievement: Research edition*. Itasca, IL: Riverside.

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

*Yeniad, N., Malda, M., Mesman, J., van Ijzendoorn, M. H., & Pieper, S. (2013). Shifting ability predicts math and reading performance in children: A meta-analytical study. *Learning and Individual Differences*, *23*, 1-9. doi:http://dx.doi.org/10.1016/j.lindif.2012.10.004

Yin, S., & Peng, H. (2016). The role of inhibition in age-related off-topic verbosity: Not access but deletion and restraint functions. *Frontiers in Psychology, 7.* doi:https://doi.org/10.3389/fpsyg.2016.00544

Yntema, D. B. (1963). Keeping track of several things at once. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *5*(1), 7-17. doi:10.1177/001872086300500102

Zelazo, P. D., & Frye, D. (1998). Cognitive complexity and control: II. The development of executive function in childhood. *Current Directions in Psychological Science*, *7*(4), 121-126. doi:10.1111/1467-8721.ep10774761

Zelazo, P.D., Blair, C.B., and Willoughby, M.T. (2016). Executive Function: Implications for Education (NCER 2017-2000) Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education.

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science*, *6,* 292-297. doi:10.1111/j.1467-9280.1995.tb00513.x

* indicates an article that was derived from our systematic literature database searches.

Table 1

Common Measures of Executive Function-Related Constructs

Task	Construct	Brief Description	Reference
Letter-memory	Updating	Participants continuously say the last three letters presented in a running series of unpredictable length, then recalled the final three letters presented after the series stops.	Morris and Jones (1990)
Word updating	Updating	Participants must remember the three smallest objects in order of presentation in each of 16 lists of 10 objects each.	Palladino et al. (2001)
Number updating	Updating	Participants must remember the three smallest numbers in order of presentation in each of 16 lists of 10 numbers each.	Carretti et al. (2007)
n-back	Updating	Participants must assess whether a presented stimulus is identical to a stimulus presented a varying number (*n*) of trials prior to the current stimulus.	Cohen et al. (2007)
Reading/listening/digit Span	Working memory	Participants must remember the last stimulus from each list of presented stimuli.	Daneman and Carpenter (1980)
Working Memory Test Battery for Children (WMTB-C)	Working memory/ phonological memory/visuospatial memory	Suite of tasks that includes digit recall, listening span, Corsi blocks task, mazes task, word list matching task, word list recall task, non-word list recall task, counting recall task, and backwards digit recall task	Pickering and Gathercole (2001)

Gordon Diagnostic System (GDS) continuous performance test (CPT) vigilance and distractibility	Inhibition	Participants press a key whenever a “1” is followed by a “9” in the absence of distracting stimuli (vigilance) and when there were flashing digit distracters (distractibility)	Gordon (1983)
Inhibition test from the NESPY II	Inhibition	Participants must name the opposite direction an arrow or shape is pointing, and then in a second task must name either the correct or incorrect direction depending on the stimuli color.	(Korkman, Kirk, & Kemp, 2007)
TextWithDistractors	Inhibition (Distracting Information)	Participants read texts with distracting words interspersed throughout and texts with no distracters. They then complete a multiple-choice comprehension test to gauge the disruption induced by the distracters.	Connelly, Hasher, and Zacks (1991)
Stroop	Inhibition (prepotent response inhibition)	Participants must override the tendency to produce a more automatic or dominant response to produce a subordinate response (i.e., name the color word printed in an incongruent color).	Stroop (1935)
Same World-Opposite World Task	Inhibition (Prepotent Response Inhibition)	Participants practice naming two digits (same-world) and then must name the opposite for each digit (opposite-world).	Gersdtadt, Hong, and Diamond (1994)
Stop-Signal	Inhibition (Prepotent Response)	Participants press the “X” or “O” key as quickly as possible when the corresponding letter is presented on the computer screen. The participant is instructed not to respond when a tone is emitted.	Logan (1994)

Hayling Task	Inhibition (Prepotent-response Inhibition)	Participants must complete high-cloze sentences with the last word missing. For half the sentences, they complete using the expected word. For the remaining sentences, participants must suppress responding with the expected word to complete the sentence with an unrelated word.	Burgess and Shallice (1996)
Antisaccade Task	Inhibition/Attentional Control	Participants must avoid capture by a flash on one side of the screen to correctly respond to a target on the opposite side of the screen.	Hallett (1978)
Semantic Sustained Attention to Response Task (SART)	Inhibition/Attentional Control	Participants complete a go/no-go task in which respond quickly to presents all stimuli except infrequent targets.	McVay and Kane (2009, 2012)
Reading/listening/digit span	Inhibition/Resistance to Proactive Interference	Analysis of intrusion errors may serve as an indirect index of inhibition ability and/or resistance to proactive interference.	Chiappe, Hasher, and Siegel (2001)
PI (Proactive Interference) task	Resistance to Proactive Interference	Participants are presented 12 lists of words belonging to four different categories. After each list, participants engage in a rehearsal-prevention task, then attempt to recall words from the preceding list. PI is indexed as the proportion of intrusions from irrelevant lists.	Borella, Carretti, and Pelegrina (2010)
Rapid Automatic Switching/Naming	Shifting	Participants alternate between rapidly naming unpredictable high-frequency words and numbers presented in rows	Denckla and Rudel (1976); Wolf (1986)

Wisconsin Card Sort Task (WCST)	Shifting	Participants sort cards according to different dimensions (i.e., color, shape, etc.) and, unless explicitly provided, must deduce the rule by which cards must be sorted from trial feedback.	Grant and Berg (1948)
Local-global task	Shifting	Participants must alternate between saying out loud the number of lines composing a larger “global” geometric figure or a smaller “local” geometric figures.	Navon (1977)
Number-Letter task	Shifting	Participants must attend to whether a number is odd/even or whether a letter is a vowel/consonant in a number-letter pair depending on the quadrant in which appears for each trial.	Rogers and Monsell (1995)
Keep-track task	Shifting	Participants must remember the last word of target categories (selected from 6 possible categories) when presented serially or randomly.	Yntema (1963)
Tone-monitoring task	Shifting	Participants must indicate when they hear the fourth tone in a series of presented tones belonging to three different tone pitches.	Larson, Merritt, and Williams (1988)
Plus-minus task	Shifting	After practicing adding three to each number on a list and subtracting three from each number on a list, participants must alternate between adding three and subtracting three to each number on a subsequent list.	Spector and Biederman (1927)
Trail-making test	Shifting	After sequentially connecting letters with drawn lines and numbers with drawn lines,	Reitan and Wolfson (1993)

		participants must alternate between connecting numbers and their corresponding letter of the alphabet.	
Animal Sorting task from the NESPY II	Shifting	Participants must sort animal cards into two categories based on changing sorting criteria.	(Korkman, Kirk, & Kemp, 2007)
General multiple pictorial classification task	Shifting/cognitive flexibility	Participants must sort word cards along two dimensions (i.e., sound and meaning/color and shape) simultaneously onto a 2x2 matrix.	Bigler and Liben, 1992; Cartwright, 2002
Digit/Word Recall	Short-term memory	Participants recall lists of digits or monosyllabic concrete and abstract words (or digits) that increase in length.	Nation, Adams, Bowyer-Crane, and Snowling (1999)

Note. References are provided for the source of the measure as operationalized by existing studies discussed in the review.

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