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What component of executive functions contributes to normal and impaired reading comprehension in young adults?

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ABSTRACT

The purpose of this study was two-fold: (a) to examine what component of executive functions (EF) – planning and working memory – predicts reading comprehension in young adults (Study 1), and (b) to examine if less skilled comprehenders experience deficits in the EF components (Study 2). In Study 1, we assessed 178 university students (120 females; mean age = 21.82 years) on planning (Planned Connections, Planned Codes, and Planned Patterns), working memory (Listening Span, Digit Span Backward, and Digit Memory), and reading comprehension (Nelson–Denny Reading Test). The results of structural equation modeling indicated that only planning was a significant predictor of reading comprehension. In Study 2, we assessed 30 university students with a specific reading comprehension deficit (19 females; mean age = 23.01 years) and 30 controls (18 females; mean age = 22.77 years) on planning (Planned Connections and Crack the Code) and working memory (Listening Span and Digit Span Backward). The results showed that less skilled comprehenders performed significantly poorer than controls only in planning. Taken together, the findings of both studies suggest that planning is the preeminent component of EF that is driving its relationship with reading comprehension in young adults.

Executive functions (EF), broadly defined as a set of abilities that an individual uses for the purpose of achieving a goal (Chan, Shum, Toulopoulou, & Chen, 2008; Diamond, 2013), have been found to predict academic achievement (e.g., Altemeier, Abbott, & Berninger, 2008; Blair & Razza, 2007; Bull & Scerif, 2001; Lan, Legare, Ponitz, Li, & Morrison, 2011; Monette, Bigras, & Guay, 2011; van der Ven, Kroesbergen, Boom, & Leseman, 2012). Conversely, individuals with learning disabilities have been found to perform significantly lower than controls on measures of EF (e.g., Brosnan, Demetre, Hamill, Robson, Shepherd, & Cody, 2002; Helland & Asbjørnsen, 2000; Peng, Congying, Beilei, & Sha, 2012; Swanson & Sachse-Lee, 2001; van der Sluis, de Jong, & van der Leij, 2004). Despite the acknowledged importance of EF in predicting academic achievement, researchers concur that different EF components may predict different academic outcomes (e.g., Latzman, Elkovitch, Young, & Clark, 2010; Miyake et al., 2000b; St Clair-Thompson & Gathercole, 2006) and that, compared to word-level reading, much less is known about the contribution of EF components to reading comprehension (Christopher et al., 2012; Kendeou, van den Broek, Helder, & Karlsson, 2014). Thus, the purpose of this study was two-fold: (a) to examine what

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component of EF predicts reading comprehension in an unselected sample of young adults (Study 1), and (b) to examine if less skilled adult comprehenders experience deficits in the EF components (Study 2).

1. Study 1

The origin of the concept of EF is usually attributed to the model of working memory advanced by Baddeley and colleagues (Baddeley, 1986, 2012; Baddeley, Della Sala, Robbins, & Baddeley, 1996; Baddeley & Hitch, 1974). According to Baddeley (1986), EF refers to 'central executive' functions that are responsible for the control and regulation of a number of cognitive processes. Some of the functions of central executive include shifting (the ability to switch between sets, tasks and strategies), selective attention (the ability to focus on a specific task while ignoring irrelevant information that is also occurring), and inhibition (the ability to deliberately suppress a dominant response when necessary). Applied to the area of reading, working memory is a resource that affects an individual's ability to carry out many of the processes associated with the construction of a text representation. Kendeou et al. (2014) further argued that the ability to keep information active in working memory is essential to inference generation. Good comprehenders are also able to maintain important information about the text while inhibiting less important or irrelevant information.

Several studies have reported significant relations between measures of working memory (particularly those that require simultaneous storage and processing of verbal information) and reading comprehension in both children (e.g., Cain, Oakhill, & Bryant, 2004; Christopher et al., 2012; Engle, Carullo, & Collins, 1991; Leather & Henry, 1994; Leong, Tse, Loh, & Hau, 2008; Seigneuric & Ehrlich, 2005; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000; Swanson & Alexander, 1997) and adults (e.g., Daneman & Carpenter, 1980; Georgiou, Das, & Hayward, 2008; Hannon & Daneman, 2001; Turner & Engle, 1989). For example, working with 7-year-old children, Leather and Henry (1994) found that working memory – assessed with counting and listening span tasks – accounted for unique variance in text comprehension (but not word reading), even after controlling for the effects of vocabulary, short-term memory, and phonological awareness. Working memory has also been found to correlate with skills that are important for comprehension, such as inference making (e.g., St George, Mannes, & Hoffman, 1997; Virtue, van den Broek, & Linderholm, 2006) and comprehension monitoring (e.g., Daneman & Carpenter, 1983; Pérez, Cain, Castellanos, & Bajo, in press; Schommer & Surber, 1986). Finally, it has been shown that less skilled comprehenders perform worse than skilled comprehenders on different measures of working memory (e.g., Cain & Oakhill, 2006; Carretti, Borella, Cornoldi, & De Beni, 2009; De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Nation, Adams, Bowyer-Crane, & Snowling, 1999; Swanson & Berninger, 1995; Swanson, Howard, & Sáez, 2006; Yuill, Oakhill, & Parkin, 1989). Researchers have attributed this deficit to either a semantic weakness (e.g., Nation et al., 1999) or to a more general language deficit (e.g., Catts, Adlof, & Weismer, 2006).

However, researchers following Baddeley regarded EF as a much broader concept that includes the abilities of goal formation, planning, carrying out of goal-directed plans, and effective performance (e.g., Lezak, 2004; Robbins, 1996; Zelazo, Carter, Reznick, & Frye, 1997). This conceptualization of EF links it to its second source of origin, namely planning (e.g., Das & Misra, 2015; Morris & Ward, 2004; see also Chan et al., 2008, for a review). Best, Miller, and Jones (2009) argued that the ability to plan is the pinnacle of EF. Planning is viewed as an essential component of goal-directed activity that involves the ability to "formulate actions in advance and to approach a task in an organized, strategic, and efficient manner" (Best et al., 2009, p. 188). In addition, good planners frequently evaluate their course of action and may even change strategies, when necessary, in order to achieve their goal. When applied to reading, planning involves choosing among a set of behaviors the ones that are necessary to achieve the goal of understanding text (e.g., Cartright, 2015; Kendeou et al., 2014). A defining feature of good readers is their ability to select reasonable goals and generate suitable means to accomplish them (e.g., Cartright, 2015; Wyatt et al., 1993).

Despite the fact that planning has been identified as an integral component of EF (e.g., Chan et al., 2008) and, by definition, critical for text comprehension, only a handful of studies have used planning measures as predictors of reading comprehension and even fewer have tested the unique and joint contributions of planning and working memory to reading comprehension. Cutting and colleagues have shown that planning – assessed with Tower of London – plays an important role in comprehension in children and adolescents, aged 9 to 15 years (e.g., Cutting, Materek, Cole, Levine, & Denckla, 2009; Locascio, Mahone, Eason, & Cutting, 2010; Sesma, Mahone, Levine, Eason, & Cutting, 2009). More specifically, these researchers have shown that planning and working memory make independent contributions to comprehension, even when the effects of inattention and decoding are controlled for. Clark, Pritchard, and Woodward (2010) also reported significant correlations between planning – assessed at the age of 4 with Tower of Hanoi – and reading comprehension at the age of 6. Finally, in a cross-sectional study that spanned ages 5 to 17, Best, Miller, and Naglieri (2011) reported significant correlations between planning – assessed with Matching Numbers and Planned Codes – and reading comprehension at every age. Unfortunately, neither Clark et al. (2010) nor Best et al. (2011) assessed working memory. In addition, with the exception of Best et al. (2011), the rest of the studies operationalized planning with a Tower task. This is problematic for three reasons: First, Tower tasks are notorious for their low reliability (see Bishop, Aamodt-Leeper, Cresswell, McGurk, & Skuse, 2001; Humes, Welsh, Retzlaff, & Cookson, 1997; Miyake, Emerson, & Friedman, 2000). Unfortunately, none of the aforementioned studies that used Tower of London or Tower of Hanoi, have reported its reliability. Second, it is not clear what Tower tasks really measure and this is clearly shown in the ways researchers have used these tasks. Some researchers have used them as measures of planning (Booth & Boyle, 2009; Cutting et al., 2009), some as measures of inhibition (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Wiebe, Espy, & Charak, 2008), and finally some others as omnibus EF tasks (Bull, Espy, &