THE EFFECT ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD) ON READING COMPREHENSION THROUGH WORKING MEMORY: A REVIEW OF THE LITERATURE

By

KYLE ROBINSON

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Faculty of Education

Queen's University

Kingston, Ontario, Canada

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Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder commonly characterized by three things. The American Psychiatric Association (2006) characterizes the three diagnostic features as:

> *Inattention* manifests behaviorally in ADHD as wandering off task, lacking persistence, having difficulty sustaining focus, and being disorganized and is not due to defiance or lack of comprehension. *Hyperactivity* refers to excessive motor activity (such as a child running about) when it is not appropriate, or excessive fidgeting, tapping, or talkativeness. In adults, hyperactivity may manifest as extreme restlessness or wearing others out with their activity. *Impulsivity* refers to hasty actions that occur in the moment without forethought and that have high potential for harm to the individual (e.g., darting into the street without looking). Impulsivity may reflect a desire for immediate rewards or an in- ability to delay gratification. (p. 61).

It presents itself in three forms: a) inattentive (where inattentive characteristics are predominantly displayed), b) hyperactive/impulsive (where characteristics of a hyperactive or impulsive nature are predominant), and c) a combined presentation (where both inattentive and hyperactive/inattentive are present) (American Psychiatric Association (APA), 2013). It is also much more prevalent in males and children (2:1).

There is also a strong correlation between academic difficulties and school in children diagnosed with ADHD of any presentation. Between 50% and 70% of children formally diagnosed with ADHD have issues related to social interactions or psychiatric concerns in adolescence, and of these 30% will continue to show signs of the disorder in their early adult lives (Cantwell, 1996; Mugalia et al., 2000).

In a learning environment, it has been shown that students with ADHD score lower than their typically developing peers on academic testing, while 35% of children diagnosed list academic underachievement as their most frequent issue (Barkley, 1991; Barnard, Stevens, To, Lan, & Muslow, 2010; Murphy, Barkley, & Bush, 2002). Exactly what causes the academic underachievement is an under-represented part of attention deficit hyperactivity disorder research, with studies tending to focus on academic or medical interventions.

Connections are often drawn between ADHD and issues with working memory. Alan Baddeley, arguably the foremost researcher on working memory, defines it as the "system or systems that are assumes to be necessary in order to keep things in mind while preforming complex tasks such as reasoning, comprehension and learning" (Baddeley, 2010, p.136). Under a model proposed by Baddeley and Hitch, working memory is multi-component built around the central executive, which controls threes subsidiary systems – the phonological or articulatory loop, the visuo-spatial sketchpad, and the episodic buffer (Appendix A) (Baddeley, 2006).

This paper will summarize and review the literature surround a very specific component of ADHD, focusing on how the disorder effects reading comprehension

in formally diagnosed students. Reading comprehension is defined as "as the process of simultaneously extracting and constructing meaning through interaction and involvement with written language" (Snow, 2002, p.11). As mentioned previously, there is little research into reading comprehension is impacted by having ADHD. Due to this, two areas of literature review. Section two will look at studies looking working memories effects on reading comprehensions. The final section will look at specific teaching strategies and interventions proven to improve reading comprehension and recall in students. Through the three sections, the argument will be made that if research shows that ADHD negatively affects working memory, and subsequently a lack of working memory affects reading comprehension, then a parallel can be drawn suggesting that ADHD negatively affects reading comprehension.

Attention Deficit Hyperactivities Effect on Working Memory

The role ADHD plays in working memory is not a well-studied field. Often a study that incorporates the effect of ADHD into working memory is looking at two or more other variables. Martinussen and Tannock (2006) studied working memory impairments in three groups: children with ADHD (n = 62), children with ADHD comorbid with a specific reading or learning disability (n = 32), and children with a reading or learning disability but not ADHD (n=15). The study used a fourth group of children without ADHD or a specific learning or reading disorder as a comparison (n = 34). The research is one of the few studies or interventions to account for the different subgroups of ADHD, as the researchers the first two groups were

subdivided their respective subgroups. In order to represent all areas of working memory, both forward recall and backwards recall tests were used, as each accesses a different function within working memory. Two tasks were used to measure the working memory of each group: verbal storage tasks, which included the Digits Forward and Digits Backward Subtests from the WISC-III (Weshler, 1999, as cited in Martinussen & Tannock, 2006), and spatial storage tasks, which included the Finger Windows task (Adams and Sheslow, 1990, as cited in Martinussen & Tannock, 2006).

Results showed that, when compared to the control or comparison group, children with ADHD were impaired in their central executive functions, but not in their storage. As well, there was no significant difference in central executive or storage function between any of the three subtypes of ADHD, except for when comparing differences in hyperactivity or inattentiveness.

Unlike Martinussen and Tannock (2006), the research conducted by Siegel and Ryan (1989) did not differentiate between different subgroups of ADHD (referred to as ADD throughout the study). Although the age of this study makes it difficult to compare to current studies, it is arguably the first study to research the link between working memory impairment and ADHD. Comparing children with reading disabilities (RD), arithmetic (math) disabilities, ADHD, and typically developing children (NA), the researchers used tasks such as a working memory sentence test – where the child needed to both insert a missing word orally, and remember all the missing words – as well as a counting exercise. Results found that all three groups scored lower on their tests than the control. The most significant

difference between the ADHD and NA groups occurred at the ages of seven and eight (Siegel and Ryan, 1989), which is around the time the disorder typically first manifests (Applegate et al. 1997).

Unlike the previous two studies, Kofler, Rapport, Bolden, Sarver, and Raiker (2010) compared only children formally diagnosed with ADHD with those considered typically developing. Those who made up the ADHD group were no co-morbid with any other disorder. Two different tasks were used, focusing on different processes. The phonological working memory task used the Letter-Number Sequencing task from the WISC-IV, in which students were presented with several numbers and a single letter, and were then required to repeat the numbers in ascending order ending with the letter. The visuo-spatial task where students were presented with an assortment of numbers on a screen, and a black dot appeared over random numbers along with a single red dot. Students were then asked to press corresponding buttons in order of the black dots, with the red appearing last. Both tasks were completed multiple times, with the set size (or the number of digits or letters to remember) increasing each time. Cameras were also used to film each task, and data was later analyzed to determine attention span during tasks. The results of each test found that children with ADHD not only had impaired working memory to the control, but that attention in was significantly impaired as the set sizes increased. The researchers argued that the findings "provide strong support for empirical models that describe working memory deficits as core features of ADHD" (Kofler, Rapport, Bolden, Sarver, & Raiker, 2010, p. 159).

Working Memory's Effects on Reading Comprehension

In discussing the effects executive dysfunction has on reading comprehension, Locascio, Mahone, Eason and Cutting (2010) refer to the possible "weaknesses in executive functioning may contribute to poor comprehension abilities in children with and without ADHD diagnoses" (p. 442). Participants in the study were divided into three groups, those with word recognition deficits, those with reading comprehension deficits, and a control group with neither. Using a variety of tests relating to different executive functions – including working memory, response inhibition, and planning, organization and self-monitoring, researchers found that children with reading disorders, especially reading comprehension, had deficits in executive function, with particular emphasis on working memory. Issues arose when the researchers failed to separate out various learning disabilities and attention disorders. However, the research findings were strong and the researchers clearly state the limitations of their work.

Cain and Oakhill (2004) found similar results in their study of 46 children, drawn from a longer longitudinal study. Using the Neale analysis of reading ability (Neale, 1989, as cited in Cain & Oakhill, 2004), children were split into two equal groups by their reading comprehension (poor and good). Two tests were administered, the first of which looked at vocabulary knowledge, memory, knowledge of syntax, general intellectual ability, and specific comprehension skills such as monitoring, inference and integration, and knowledge about story structure. Children considered poor comprehenders were found to be lacking in verbal working memory, among other skills. However, unlike some other studies focusing

on working memory in mathematics, the participants were not lacking in digit working memory. Cain and Oakhill theorize, "it may be that poor comprehenders have an impairment with processing complex information [a subset of working memory] in the verbal domain, but not a general reasoning impairment" (2006, p. 693).

Using adult readers, rather than children, Hannon (2012) studied the effects of working memory and reading comprehension as well as higher and lower level word processing to produce a more comprehensive model of reading comprehension. The previous model, known as the Cognitive Components and Resource Model (CC-R), theorized working memory as an indirect influence being mediated through knowledge integration (see Appendix B). Through a large-scale study of 150 University of Texas students, Hannon (2012) collected data on reading comprehension ability, higher- and lower-level word processing and working memory, using a variety of measures for all three. The researcher's analysis found that working memory exerts both a direct and indirect influence on reading comprehension, which contradicts earlier models (see Appendix C).

Two subsections of working memory – attention shifting and inhibitory control - and their effect on reading comprehension were studied by Kieffer, Vukovic and Berry (2013) as part of a longitudinal research project "designed to examine the developmental course and cognitive predictors of academic abilities in a cohort of diverse students in an urban context" (p. 337). The researchers performed tests on a total of 120 students (with a mean age of 9 years, 11 months), measuring reading comprehension, attention shifting, inhibitory control, language

comprehension and word reading. To analyze the data, "multivariate path analysis was implemented to investigate multiple simultaneous variable of interest, which estimating both direct and indirect (partially mediated) associations of each [executive function] dimension with reading comprehension" (Kieffer, Vukovic, & Berry, 2013, p. 338). Through this analysis, Kieffer et al. found that both subtypes of executive functions studied contributed to reading comprehension, and "support[s] emerging evidence for the importance of these two distinct dimensions of [executive function] in early academic development" (2013, p. 342). As well, they suggest that future models of reading comprehension include reference to executive functions. Although this study does not include reference specifically to working memory like others reviewed, it is important to note the emphasis Kieffer et al. place on executive functions, an umbrella term for higher cognitive processes that also includes working memory (Kieffer et al., 2006; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). As such, if the authors argue for the inclusion of executive function, this includes working memory.

Interventions and Academic Strategies

Although there is little study into the effect ADHD has specifically on reading comprehension, there have been a number of studies targeting academic strategies and interventions to boost comprehension. Beike and Zentall (2012) studied the effect of "content novelty" on the reading comprehension of children with ADHD and children with RD. Three groups were formed, one of clinically diagnosed students with ADHD (n=16), one of reading difficulties, as based on scores on the Woodcock

Johnson Test of Achievement–III (Woodcock, McGrew, & Mather, 2001, as cited in Beike & Zentall, 2012) (n = 16), and one of typically developing students (n = 16). To create high-interest fables, researchers made several changes to the existing fables:

> (a) verb changes from passive to active/emotional (clinging vs. walking), (b) character changes from familiar to less familiar (fox vs. orangutan), (c) adjective changes from common to unusual (brown vs. hairy) or adding an adjective (great horned owl vs. gray fox), (d) end speaker changes from familiar to less familiar/vivid (cat vs. tarantula), and (e) story ending changes in surprising/incongruity (continued on her way home vs. all the milk was spilled) (Beike & Zentall, 2012, p. 532).

These high-interest fables were mixed with those left unchanged and distributed to participants who read and answered questions on each. Students with ADHD made significant and consistent gains in reading comprehension when presented with a high-interest fable.

Not only does the novelty of content increase reading comprehension, but Belfiore, Grskovic, Murphy and Zentall (1996) found that colour of text and background also produced significant changes in ADHD diagnosed readers. Using a small sample size of three, formally diagnosed students with hyperactive/inattentive ADHD, the researchers used developmentally appropriate stories divided into three passages of equivalent line length. Passage one was presented as a typical printed work, with black, 12-point font on white paper. Passages two and three were highlighted with Crayola markers, with the first using muted colours (such as sky blue) and the second using bolder, more vibrant colours

(such as fiery orange). Stories varied in length, and as such, sometimes all three passages were not visible on page one. Students then answered comprehension questions on each story. Researchers found that "nonspecific color added to the later part of a lengthy task, but observable throughout the task may help students with LD and ADHD" with reading comprehension (Belfiore, Grskovic, Murphy, & Zentall, 1996, p.436).

Beyond changing the text or colour of the text, teaching strategies developed for struggling readers diagnosed with ADHD have also been completed by Dilberto, Beattie, Flowers and Algozzine (2009). In their study, the researchers identified 44 children who were diagnosed with ADHD and were considered poor readers. Researchers applied an intervention developed by Dilberto and included 60-mini lessons consisting of "four components: (a) Group Review, b) New Information (for 12 lessons), (c) Word Reading, and (d) Written Spelling" (Dilberto, Beattie, Flowers & Algozzine, 2009, p. 19). New information included learning about syllable patterns, as well as syllabication rules, steps and accenting patterns. Word Reading involved practicing reading nonsense and low frequency words, while written spelling involved writing the low frequency or nonsense words based on oral pronunciation. These tasks were completed in addition to the existing common curriculum.

Results from testing before and after instruction showed the treatment group, consisting of the students diagnosed with ADHD, "benefitted rom systematic intervention focused on critical literacy skills" (Dilberto et al., 2009, p.25). There was a significant increase in reading comprehension skills, while an increase was

also seen in word identification and word attack skills. As such, the researchers recommend using Dilberto's Syllable Skills Instruction Curriculum in addition to the common curriculum as a way of increasing reading comprehension in students diagnosed or at risk for ADHD or RD.

While the prior reviewed strategies were studies using elementary school age children, Johnson, Reid and Mason (2012) studied reading comprehension in high school students with ADHD. Three students, formally diagnosed with ADHD and teacher and state identified as poor comprehenders, were used to determine the effectiveness of a reading comprehension strategy known as Think Before Reading, Think While Reading, Think After Reading (TWA). This strategy, when taught using self-regulation, is a nine-step program, using checklists and charts, to implement common reading comprehension strategies. When implemented by the researchers, reading comprehension in the three students increased, as there was an immediate and pronounced increase in all three measures used.

Conclusion

Literature surrounding the complicated interaction between ADHD and reading comprehension focuses mainly on the interventions and teaching strategies available to boost reading skills. Due to the fact that ADHD is often diagnosed comorbid with reading disorders (APA, 2013), there is an unmentioned assumption that strategies focused specifically around RD will work regardless of a diagnosis.

What limited literature there is on the subject, studies have shown that ADHD impairs in working memory, while differing studies have shown that

impairments in working memory negatively affects reading comprehension. As such, a connection can be drawn suggesting that ADHD has the potential to directly affect reading comprehension. While this impairment in working memory my not be the only way ADHD affects comprehension, it provides an avenue for developing tailored teaching strategies and interventions.

Future studies in this field need to further research the affect ADHD has on reading comprehension. Studies comparing the reading comprehension of typically developing students and those diagnosed with ADHD could begin to prove that all students with ADHD have reading comprehension issues. Similarly, future studies should begin to purposefully select participants based on a particular subgroup of ADHD. While several of the studies reviewed tend to display the numbers of inattentive, hyperactive/impulsive and combined participants, the data is typically not displayed to show the difference. Studies focusing specifically on one subgroup would allow for development of even more specific interventions and teaching strategies.

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Note: studies reviewed for this paper are denoted with an asterisk (*)

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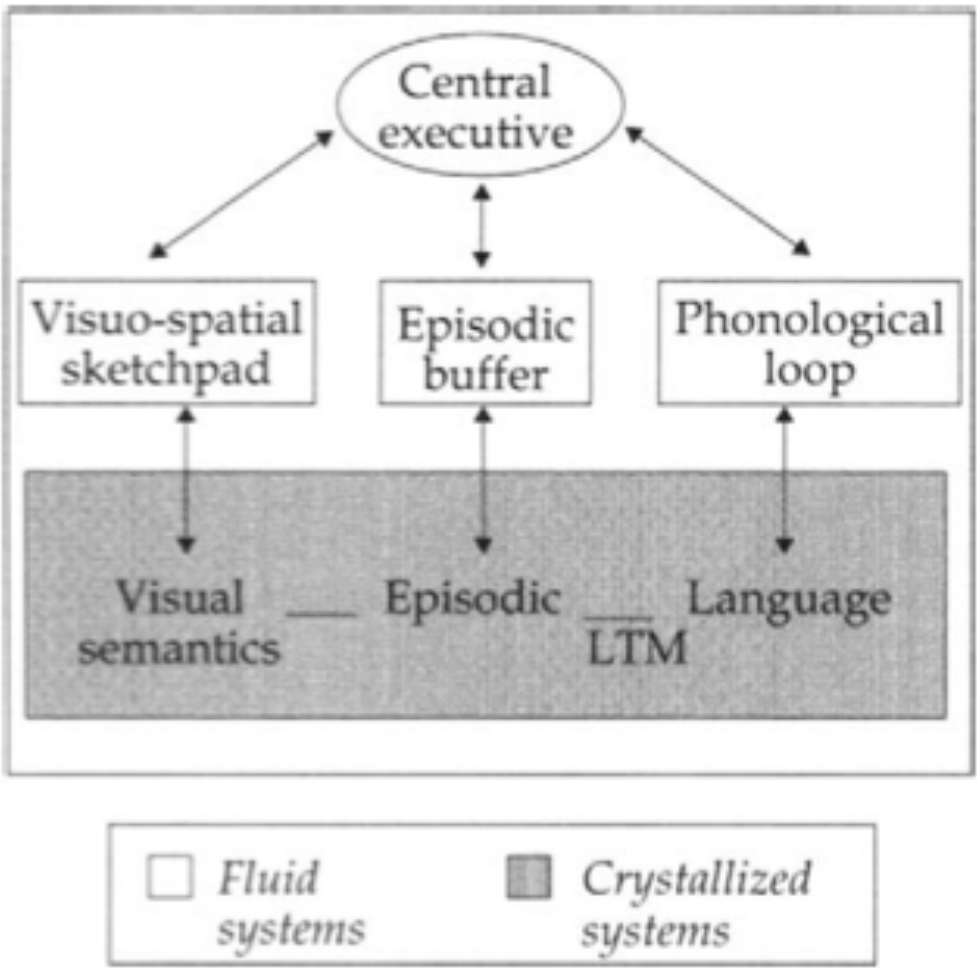
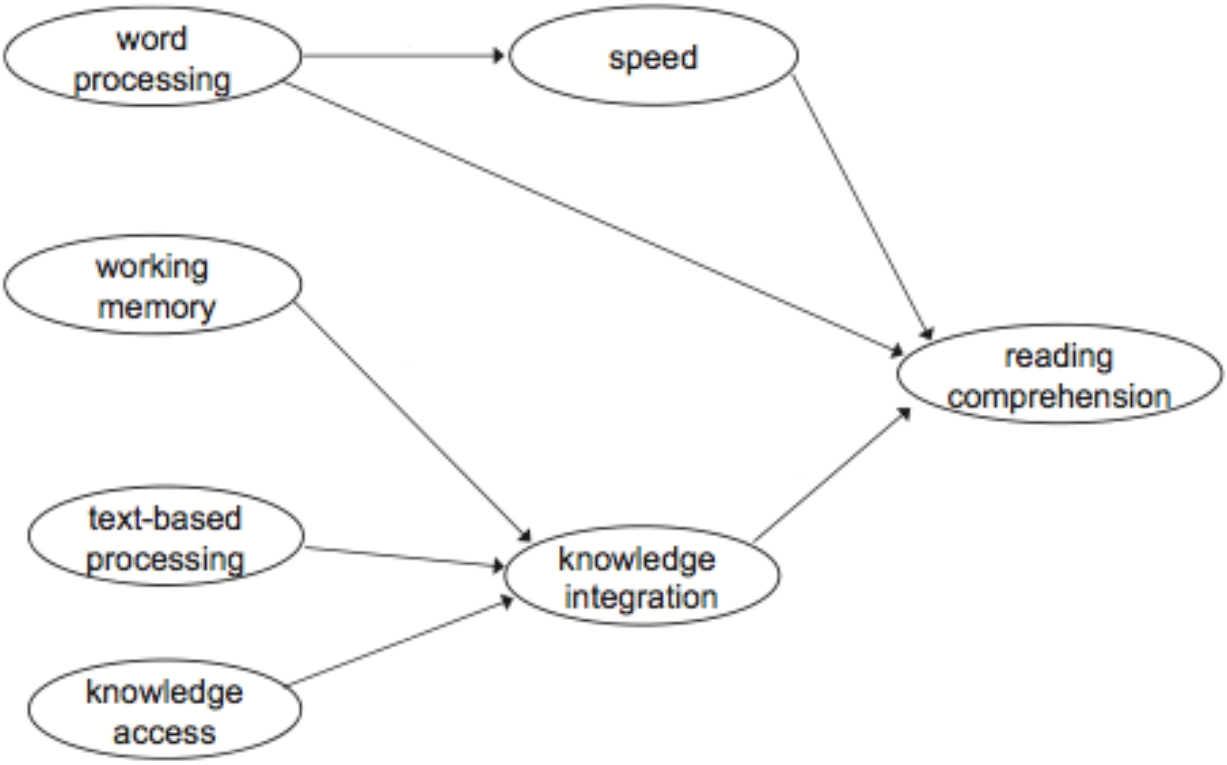
Appendix A



Baddeley's (2010) model of working memory, which is broken into the central executive (top, in an oval) and its three subsystems (in rectangles) – visuo-spatial sketchpad (left), episodic buffer (middle), and phonological loop (right).

Adapted from: Baddeley, 2010, p. 24.

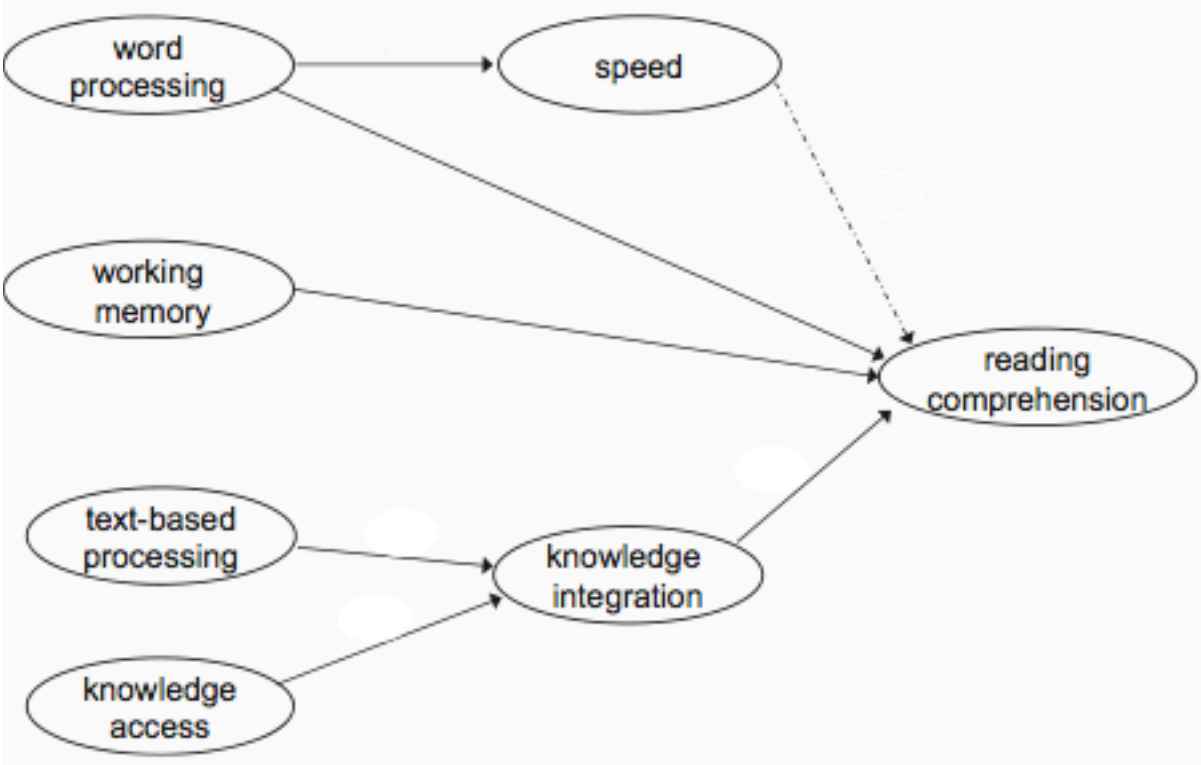
Appendix B



The Cognitive Components and Resource model of reading comprehension used to inform Hannon's (2012) study. Notice that working memory is mediated through knowledge integration.

Adapted from: Hannon, 2012, p. 129.

Appendix C



The model proposed by Hannon (2012). Notice that working memory now has a direct, significant impact (shown through the dark arrow) on reading comprehension, and is not mediated through knowledge integration.

Adapted from: Hannon, 2012, p. 142.