A Review of Models of Reading Comprehension with Implications for Adults with mTBI and the Campus Reader

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Introduction

This purpose of this report is to review theoretical models of reading comprehension and to consider how key concepts relate to adults with mild traumatic brain injury (mTBI) and the CampusReader project. Below, the overarching theoretical principles from the review are briefly summarized.

Overarching Principles

1. Text comprehension is a dynamic, interactive process between the individual, the text, the reading activity (i.e., purpose), and the larger socio-cultural context for reading (Best, R.M., Guthrie, J. T., 2002; Rowe, M., Ozuru, Y. & McNamara, D.S., 2005; RAND Reading Study Group, 2002; Stanovich & West, 1995; Verhoeven, L. & Snow, C.E, 2001)

2. Interactions occur within the individual, involving both top down and bottom up reading and cognitive processes (Glushko, 1979; Glushko, 1981; Kintsch, 1998a; Kintsch, 1998b; Kintsch & Van Dijk, 1978; LaBerge & Samuels, 1974; Lundberg, 1991; Rumelhart, 1977; Rumelhart & McClelland., 1986; Stanovich, 1980; Van Dijk, & Kintsch, 1983; Verhoeven & Perfetti, 2008).

3. Successful comprehension and retention depends on the ability to reliably access and integrate background knowledge, and the ability to generate, maintain and update iterative forms of meaning constructions (Baddeley, 2000; Ericcson & Kintsch, 1995; Verhoeven & Perfetti, 2008; Zwann & Radvansky, 1988).

Brief Summary of Models Reviewed

An empirically grounded theoretical framework is needed to describe the reading comprehension process in order to (1) anticipate the aspects of that process that can be disrupted as a consequence of an acquired brain injury, and (2) guide the Campus Reader strategy and feature selection process. For this project, we describe four models drawn from the education and cognitive psychology fields to conceptualize the aspects of reading we believe are most pertinent to the purposes of the CampusReader. Viewing reading from these multiple conceptualizations is necessary to identify potential breakdowns in the reading process and to generate ideas for strategy supports. At the broadest level, we present a model that captures the interactive processes occurring between the individual, the text, and the reading activity (RAND Reading Study Group; 2002). Next, we describe a model that conceptualizes the overall reading processes activated within the individual (Perfetti, Landi, & Oakhill, 2005). To highlight aspects of comprehension we anticipate are particularly difficult for our target population, we review more fine-grained conceptual factors specific to the construction of meaning once word recognition has occurred (Kintsch & van Dijk, 1983; van den Broek, 2005; Zwann & Radvansky, 1998), and offer a graphic portrayal of those factors. Finally, we present a model to account for the role of working memory, retrieval and encoding processes (Baddeley, 2000) in reading comprehension.[1] . Overall, these four models collectively capture aspects of the reading comprehension process particularly pertinent to the CampusReader project.

[1] Note that we recognize that the conceptualization of reading and reading comprehension processes in particular continues to be actively debated and is driven by ongoing inquiries. We selected models we believe have particular utility for guiding our intervention project. However, we remain open to questioning assumptions made by the selected models, and to revising our theoretical grounding when empirical findings from other researchers or derived from our study suggest practical implications for doing so (i.e. a need to revise our intervention approach).

Reading in Context: A Heuristic to Conceptualize Reading Comprehension

A complete view of the reading comprehension process must account for the dynamic, interactive processes that occur between a reader, text, and the reading activity, within a range of socio-cultural factors. The RAND Reading Study Group (2002) depicts the interaction between these elements (see Figure 1). Intended by RAND as a heuristic to guide reading research program development, we adapt the model to highlight the implicit bio-psychological and external socio-cultural factors particularly pertinent to people with reading comprehension deficits due to acquired brain injury.

Reader, Text and Activity

The reader element of the figure refers to factors that the individual reader brings to the reading comprehension process. This element encompasses reading and cognitive skills, as well as individual psychosocial and biological factors that influence the reading process. The text element includes factors inherent in the reading material. Examples include text genre (i.e. narrative vs expository), level of text (e.g, introductory vs advanced) and characteristics such as font, graphics and layout. The activity element refers to the reader's purpose and goals (e.g., leisure reading vs. reading to learn) for reading text. Although the elements are defined separately and somewhat statically, the RAND group emphasized that these elements are interrelated, and dynamic. The influence of the reader, text and activity elements will vary across the pre-reading, reading and post-reading phases of the reading process (RAND Reading Study Group, 2002).

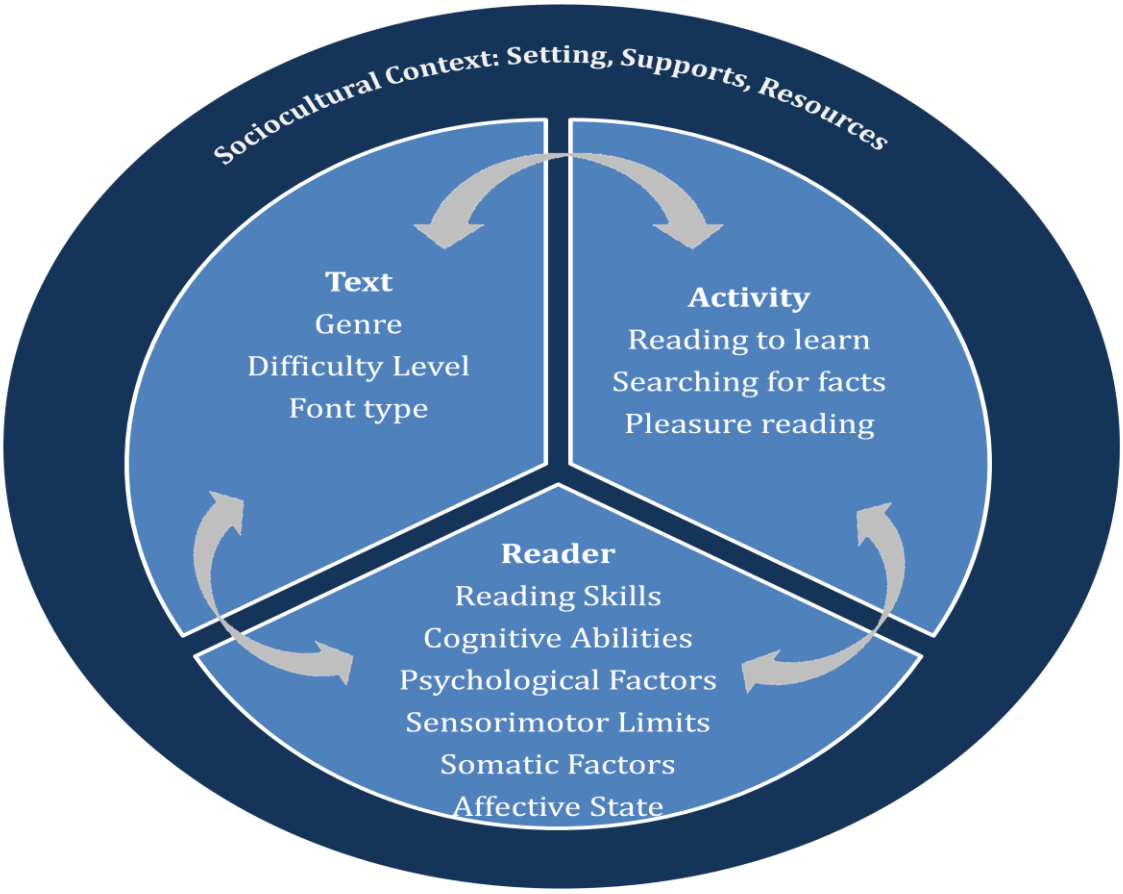
Sociocultural Context

The sociocultural context is the environmental backdrop for the reading comprehension process Factors including, "economic resources, class membership, ethnicity, neighborhood, and school culture, can be seen in oral language practices, in students self-concepts, in the types of literacy activities in which individuals engage, in instructional history, and of course in the likelihood of successful outcomes (RAND Reading Study Group, 2002; pg. 17). " Sociocultural context also includes factors such as setting variables, such as noise or lighting, or the timing of the activity.

Implications for the CampusReader

The RAND heuristic is useful for explaining the focus of the CampusReader project and for highlighting the aspects that will need to be considered as the project is developed. The CampusReader project primarily intervenes in the *reader* elements. The project focuses on developing reading strategies and supports to maximize reading comprehension performance. An individual factor our target readers will bring the reading comprehension process will be a history of mild traumatic brain injury with associated psychological and cognitive vulnerabilities that affect reading comprehension. The *text* elements will be predetermined and consist of digitally-presented introductory college-level expository text. The physical text presentation may be modified as part if the reading support strategies generated on the project. *Activity* elements are also predetermined with a defined purpose of reading to learn. *Sociocultural factors* particularly pertinent to this project will include environmental factors that characterize our population who will mostly be veterans with combat-related brain injuries.

Figure 1: The CampusReader Heuristic for Thinking about Reading after ABI (Adapted from RAND Reading Study Group, 2002)



Reading Skills of the Individual: An Interactive Activation Model for Word Identification and Comprehension

Reading is an iterative, interactive process. Historically, models were developed that represented the reading process as either "bottom-up," starting with the perceptual processing of text and moving upward through word recognition to comprehension, or "top-down," starting with activation of prior knowledge and proceeding downward (see McCormick, 1988 for full review). Emerging from decades of research in the fields of psychology and education, interactive models of reading suggest that bottom-up and top-down processes are active simultaneously. Multiple models have been posited that similarly describe the reading process in this manner with variations regarding the actual subcomponents detailed, the import of each and the relationships between them, and the timings of interactions (e.g. Glushko, 1981; Kintsch & Van Dijk, 1978; McClelland & Rumelhart, 1981; Rumelhart, 1977; 1981; Stanovich, 1980; Verhoevan & Perfetti, 2008). In Figure 2 we present an adaptation of one such model that captures this dynamic process (Perfetti, Landi & Oakhill's, 2005). The conceptualization has two main reading processes, word identification and comprehension. Both main reading processes contain sub-component skills or processes that support the overall goals of word identification and comprehension.

Word Identification

At the word identification level, orthographic and phonological processes occur more or less simultaneously to lead to word retrieval (McClelland & Rumelhart, 1981); importantly, both processes interact with higher level processes to resolve ambiguities. While debate continues about the relative role of each sub-process within any given word-identification task, a large consensus exists within the research community about the fundamental role of phonological processing in reading development, and the strength of it as a predictor of reading ability, even in adults (Stanovich, 2000). In addition, there is general agreement that as reader skill develops, there is less reliance on top-down processes to facilitate the word-identification process in particular (Stanovich, 2000). That is, the bottom-up processes involved in word recognition become automatic over time for skilled readers. If this does not occur, the continued reliance on top-down processes to support word recognition means that word identification involves a higher cognitive load for less-skilled readers.

Comprehension Processes

Word identification leads to the process of activating and constructing meaning at the next level of reading: comprehension processes. Comprehension processes result in three levels of representation of a text's meaning. First is the sentence level representation (sometimes called the surface level), which is literally a word-for-word rendering of the text being read. Second is the proposition level of representation, in which the reader extracts the core ideas from the literal text. With word meaning available, syntax is parsed to establish relations between words leading to construction proposition level meaning. Third is the situation model, which is the highest level representation of the text's meaning and represents the integrated situation described in a text. Extending beyond literal and propositional representations, situation models describe the representation constructed when readers integrate and update what they already know about the topic into a more complex and holistic conceptualization of it.

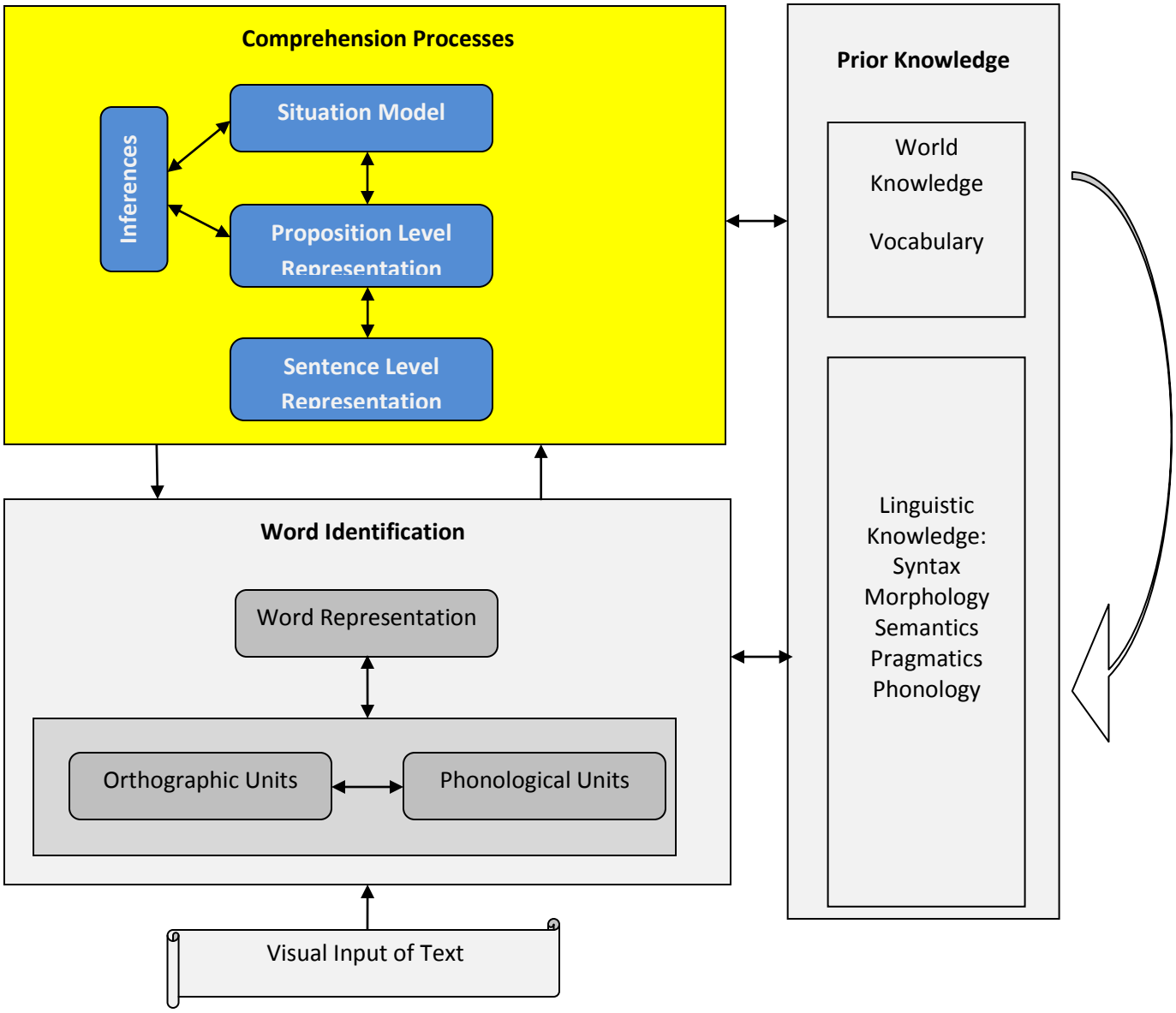
Prior Knowledge

Influencing the successful construction of both of these levels of comprehension are the reader's linguistic and general world knowledge. The original model does not define the interaction between prior knowledge with the two reading components. Language skills, language knowledge and general world-knowledge are accessed during the reading process, however, the extent and timing of the activation, and the nature of the relationship between different types of background knowledge is not clear. For the purposes of the CampusReader project, the model was adapted to emphasize the factors most pertinent to developing reading comprehension supports.

Implications for CampusReader

The interactive model is particularly relevant to the CampusReader project because it recognizes the simultaneous processing of written text and the activation of existing reader knowledge. Overall, as Figure 2 attempts to illustrate, multiple interactions are occurring both simultaneously and iteratively, both within each process and in two directions between each process. Isolating the effects of one subcomponent on reading comprehension will be challenging. First, while specific deficits may exist within a particular sub-component, the ultimate effect on the overall reading process could be apparent in another component. Second, successful performance on a task that seems to depend on a particular sub-component is not an indication of that sub-component's processing integrity as it could be masked through compensation by another sub-component. This conceptualization has strong implications for the reading strategy matching process that will be part of CampusReader.

Figure 2: An Interactive Activation Model Reading (Perfetti, Landi & Oakhill, 2005)



A Deeper Look at Reading Comprehension: Construction of Mental Representations or "Situation Models"

As described in the previous section, the situation model level construction of meaning goes beyond just a summative interpretation of the literal meanings extracted from the text. Using a sequential and iterative process, readers integrate and update what they already know about a topic with what they are learning to create an increasingly complex and holistic mental representation of the text. If comprehension has occurred successfully, this process also results in readers updating their general knowledge about the topic.

Event Indexing

Situation models have been studied extensively in the reading of narrative texts and from a narrative perspective they can be characterized according to a set of conceptual dimensions or event indexes (see Britton & Graesser for review, 1995; Kintsch & van Dijk, 1983). Emerging from research on narrative production and comprehension, the five dimensions typically discussed are: time, space, causation, motivation, and protagonist. Although these five dimensions are not the only ones possible, they have empirical support and can also be adapted to fit other genres of text (Zwann & Radvansky, 1998). For example, a text on the history of the United States would include time dimensions, corresponding to the temporal ordering of events; space dimensions, corresponding to changing geography with history; causation dimensions, to explain how key events precipitated others (e.g. taxation -> Boston Tea Party); motivation dimensions, corresponding to impetus for change in society; and protagonist dimensions, corresponding to historical persons.

The Shift from Situation to Schema

The description of specific situations creates a "token" mental representation; for instance, readers encountering their first account of the Revolutionary War would have an individual token representation for that war. Over time, related situation models form a stereotypic mental representation, or "type," called a "schema." For example, after encounters with multiple accounts of the Revolutionary War, a reader would develop a schema for this specific war that is not reliant on any one account or experience. Moreover, upon encounters with accounts of other wars, a reader would also develop a schema for the abstract idea of war itself.

Updating Schemata

The construction of "situation models" happens over time while reading and leads to the updating of schemata stored in long-term memory (van den Broek, 2005; Zwann & Radvansky, 1998). [2] To understand this process, we must distinguish three types of mental representations: the mental representation (i.e. situation model) that develops as a person reads the text that is specific to that text, the mental representations that are retrieved from related schemata in long-term memory, and the mental representation(s) that are updated, or "integrated," versions of schemata based on new information gleaned from the situation model. These latter representations can be thought of as integrated mental representations that are then encoded into long-term memory.

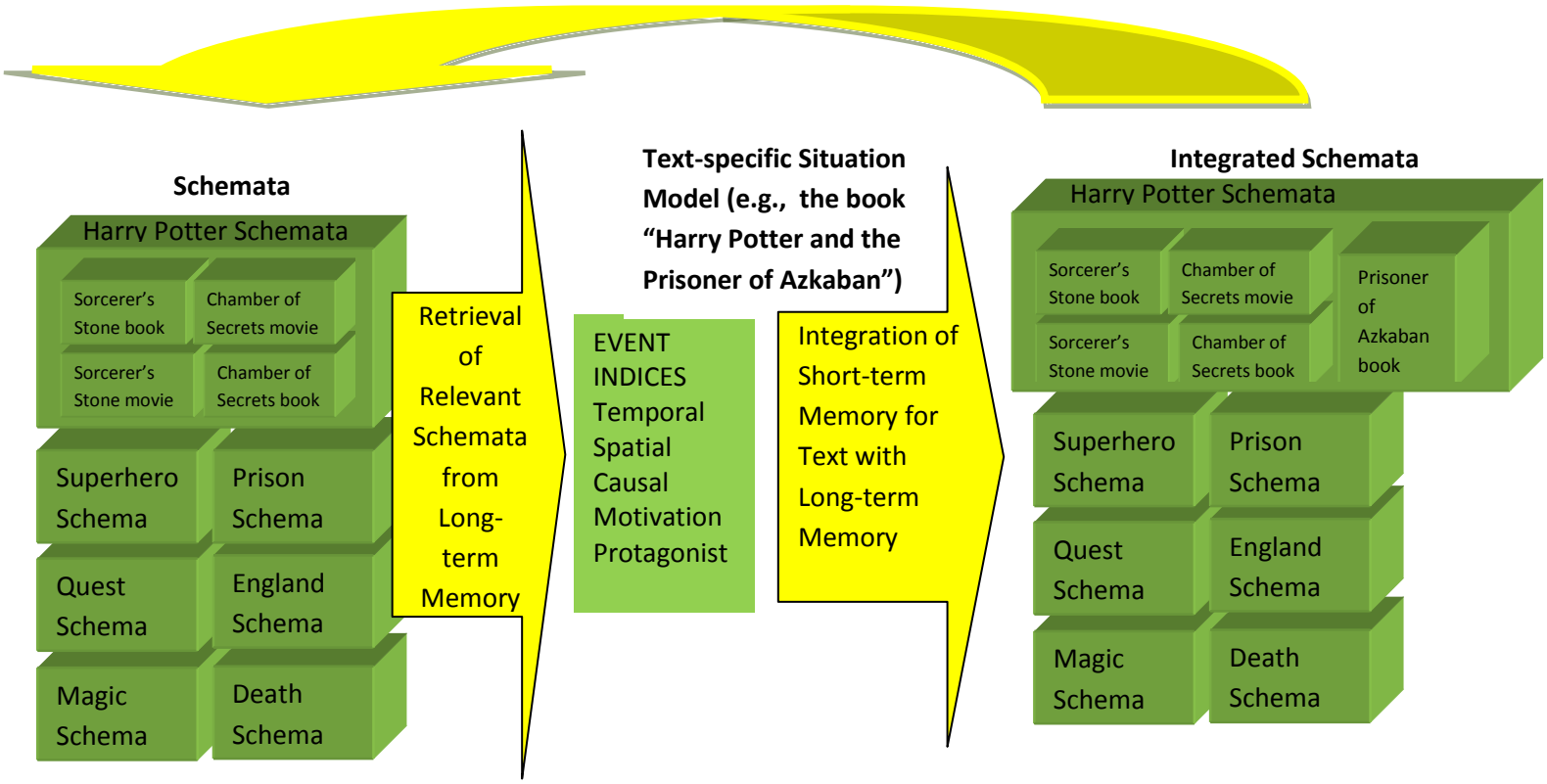
The ease with which situation models are integrated depends on how many aspects of the dimensions are shared between prior knowledge and the iterations of the situation model that develop as the text is being read. Congruent information between dimensions results in more rapid updating into a situation model than incongruent information. Conflicting or incongruent information slows or even interrupts the integration process. Readers either resolve incongruent information by doing one of more of the following: clarifying new information, revisiting old information, identifying commonalities, and suppressing outdated information. However, readers may also proceed with reading without trying to resolve an incongruence, in which case the integrity of the situation model weakens as the process progresses. Figure 3 offers a graphic conceptualization based on the situation model literature that helps to frame construction of meaning over time. Using *Harry Potter* as an example, the figure depicts what schemas a reader may activate as the start the reading process. As new information is obtained, the reader compares, and evaluates event indices, then ultimately integrates the updated representation into an integrated schema in long-term memory. Although these factors are conceptualized as happening sequentially, they may not necessarily happen in the same order every time. In fact, they may not even be discrete processes. Most importantly, they will vary depending on the nature of the reading activity, the individual, the text, and contextual factors.

[2] Although here we focus on that process specific to reading, this process is not unique to reading. For example, a model constructed while reading may be revised later while listening to a class lecture regarding the same topic.

Implications for CampusReader

Event indexing and situation model integration have particular utility from an intervention perspective. Particularly pertinent to the CampusReader project is the iterative and dynamic depiction of the construction of meaning, and the concept of indices as the driving conceptual frame for this construction. These aspects help to theoretically ground several reading comprehension strategies that have been shown to be effective for struggling readers. For example, strategically activating background knowledge based on purpose for reading, or facilitating deep questioning during the reading process to facilitate integration of new information with prior knowledge are strategies that lead to improved reading comprehension outcomes (e.g. Wong, 1985); the figure helps to generate hypothesize why this might be.

Figure 3: Mental Representation of Construction and Updating



Working Memory and Reading Comprehension

Reading comprehension depends upon a number of cognitive processes. Readers must be able to "hold onto" new information as it is being read, while retrieving relevant information from background knowledge. As described in the previous section, the reader must then integrate information from these two sources to construct an intermediate representation of meaning. Doing so requires the ability suppress the irrelevant aspects, and to select the relevant aspects. These relevant aspects must then be maintained in working memory while the information is manipulated to identify, interpret and resolve incongruencies in the information. This process is repeated iteratively as intermediate stages of understanding (i.e. integrated schemata) are continually updated. Integrated schema must ultimately be encoded into long-term memory. All of these "higher level" processes must happen while "lower level" processes such as word identification are also at work (Baddeley, 2000; Ericcson & Kintsch, 1995).

Phonological Buffer, Visuospatial Buffer and Central Executive

A well-accepted model of working memory pertinent to our work is Baddeley's revised model of working memory (2000; Figure 4) based upon Baddeley and Hitch's seminal model (1974). The significance of the original model was that it shifted the prevailing focus from short-term memory as a temporary store to the concept of working memory, with three components that contributed to the active maintaining of information until it was either stored in long-term memory or forgotten. The new model maintains the three components of the original model: two "slave stores," the phonological buffer and the visuospatial buffer, which are modality specific systems that maintain auditory, and visual information, respectively, until the third component, an executive processor actively direct attention to the information. The executive processor is the mechanism charged with directing information to the proper stores within the working memory system, and then out again so the information could be manipulated. The revised model adds a third buffer, the episodic buffer as described below.

Episodic Buffer, and Direct Access to Long-Term Memory

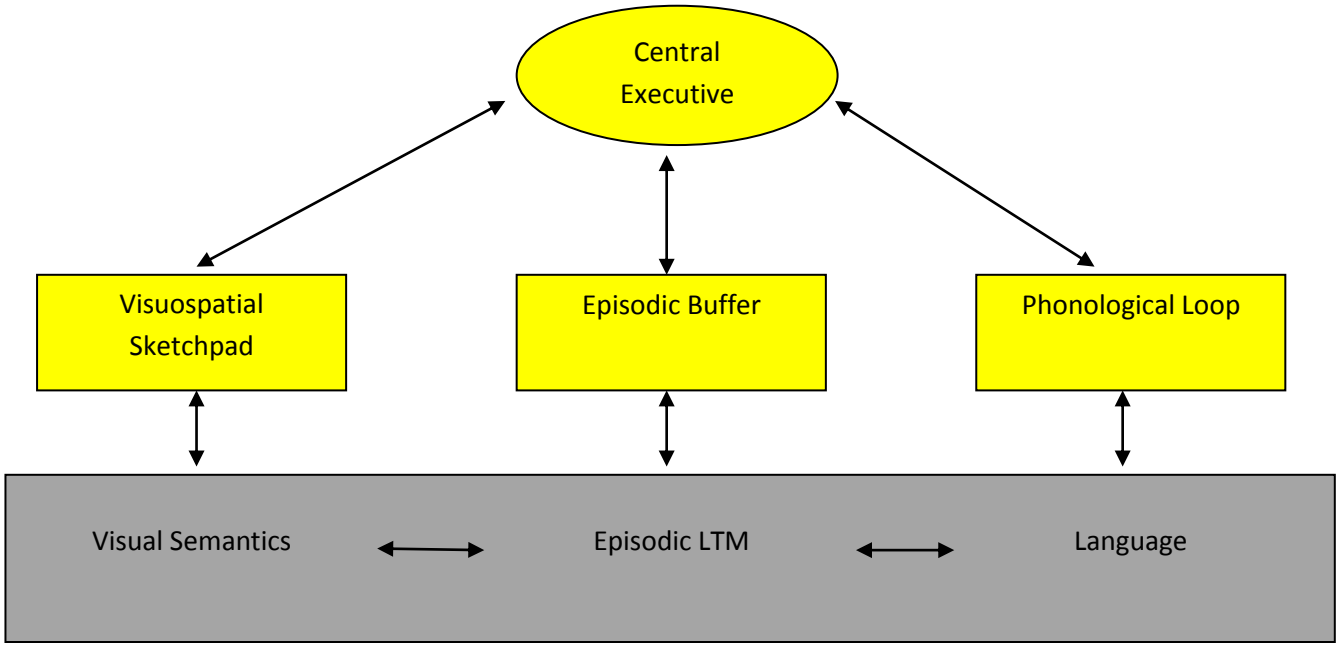
Multiple researchers in cognitive psychology in the late 1990's focused on defining where information is manipulated as it begins to be processed., Ericsson, & Kintsch's model of "Long-Term Working Memory" (1995) was particularly pivotal and accounted for how complex cognitive skills could be performed rapidly without overwhelming working memory, a limitation of the original Baddeley and Hitch model (1974). Baddeley took on the issue by positing the episodic buffer. The nomenclature was intended to align with the conceptualization of "events," described

earlier. That is, during reading, intermediate meaning states are constructed and maintained in the episodic buffer. The revised model also specified that buffers have direct links to and from correlates in long-term memory. Thus, while the central executive still directed attention to the contents within each buffer, the construction, maintenance and encoding of these representations is not dependent on central executive control. Thus, access to structures in long-term memory is under control of "priming effects," facilitating more rapid retrieval and encoding of information from and to the schema. Although multiple models including Ericcson & Kintsch (1995) account for how efficient information integration and accessibility might occur, Baddeley's revised model, with its retained conceptualization of a central executor charged with controlling attention, will be particularly useful for grounding strategy selection for the CampusReader project.

Implications for CampusReader

Hallmark cognitive symptoms following acquired brain injury are impairments in working memory and executive control. CampusReader will be designed to support the working memory capacity and control of information for readers through the use of strategies that facilitate the most effective use of the buffers and the central executive. Examples of supports to improve reading comprehension skills that are diminished due to impairments in these cognitive systems include encoding strategies that require deeper processing and preview strategies that activate background knowledge.

Figure 4: Revised Model of Working Memory (Baddeley, 2000)



Supporting the Reader: Anticipating Sources of Disruption and Identifying Empirically Supported Compensatory Strategies

Brief Review of ABI and Reading.

With a theoretical basis for understanding the reading comprehension process, we now consider more specifically the types of reading comprehension impairments experienced by adults with no prior reading issues after they suffer mild traumatic brain injury. The consequences of acquired brain injury are highly individual with multiple patterns of deficits possible, ranging along a continuum of severity. The focus of the CampusReader project is those individuals with mild traumatic brain injury who, while still diverse in terms of underlying neurological injuries, voice challenges in high level understanding and retention of reading material for school and work (Lezak, 1991, 1995; Salmen, 2004). The little available research suggests that lower level processes required for word recognition and single sentence comprehension remain intact (Lezak, 1995; Salmen, 2004). Breakdowns seem to occur within reading tasks that depend upon higher level processes, such as inferencing, construction of situation models, encoding and retrieval. The problems are thought to stem from impairments in executive processing, working memory, and retrieval that typically occur following mild acquired brain injury (Sohlberg & Mateer, 2005). For example, difficulties with working memory may challenge the reader to "hang on" to incoming information long enough to integrate with prior information. Reduced self-monitoring, an executive function, may limit the ability to identify and respond to gaps in understanding. The CampusReader project seeks to evaluate and develop customized and dynamic strategy support systems delivered via the CampusReader to maximize reading performance.

Introduction of Strategies.

The special education literature has empirically validated a number of reading strategies effective in populations of struggling readers, including individuals with delayed reading skill acquisition, attention deficit disorder (ADD), and second language learners. In addition, substantial evidence from the cognitive rehabilitation literature supports the efficacy of using cognitive and meta-cognitive strategies use and external aids to improve performance in a number of functional areas including reading (Stine-Morrow et al, 2008, Caretti et al, 2005, Todis et al, 2005; Sohlberg et al, 2004; Kintsch & Van Dijk, 1978). The CampusReader project has drawn upon this these literature bases, in addition to analyzing clinical profiles of readers with mild traumatic brain injury

in order to identify potential reading strategies useful to the target population. The strategies have been further evaluated for their theoretical basis with respect to the reading and cognitive models presented in this document. Table 1 outlines sample strategies being considered based on anticipated sources of disruption, and grounded by the theoretical reading and cognitive models reviewed.

Table 1:

Theoretical Reading Processes	Key Cognitive Processes Activated	Anticipated Sources of Disruption for Struggling Readers after ABI	Sample Strategy Types for Struggling Readers after ABI
• Activate background knowledge *schema* in long-term memory. • Retrieve relevant *enduring situation model* from long term memory.[3,4,5,8,9]	• Executive functions/self monitoring • Activation and retrieval from long-term memory.	• Insufficient background knowledge • Difficulty activating background knowledge schema • Difficulty retrieving appropriate situation model from LTM	• Identify reading purpose and goal, • Preview content, • Predict task difficulty, • Create time-ordered agenda including scheduled breaks, • Prepare organizing strategy (e.g. select graphic organizer),

Theoretical Reading Processes	Key Cognitive Processes Activated	Anticipated Sources of Disruption for Struggling Readers after ABI	Sample Strategy Types for Struggling Readers after ABI
• Construct *emerging situation model* while reading • Integrate *emerging and enduring situation models* into *integrated situation model.* • Construct inferences • Resolve incongruencies • Suppress irrelevant information • Iteratively encode updated situation into long-term memory. • Maintain updated iterations of integrated situation model while reading.	• Executive processes / self monitoring • Short-term working memory/explicit attention, • Long-term working memory/episodic buffer/implicit attention, • Encoding/Recall	• Insufficient self-monitoring of understanding. • Difficulty maintaining emerging and integrated situation models. • Difficulty integrating new and prior information to construct inferences, resolve incongruencies. • Difficulty suppressing irrelevant information. • Difficulty encoding updated situation model.	• Highlight main ideas, • Summarize iteratively, • Re-arrange information using organizing strategy, • Monitor pacing, • Update time-ordered agenda, • Self Question[6]/Self test.

Theoretical Reading Processes	Key Cognitive Processes Activated	Anticipated Sources of Disruption for Struggling Readers after ABI	Sample Strategy Types for Struggling Readers after ABI
• Continue to construct and update integrated situation model. • Encode updated situation model for long-term storage.	• Executive processes/self monitoring • Short-term working memory/explicit attention, • Long-term working memory/episodic buffer/implicit attention, • Encoding/Recall	• Same as during phase plus: • Poor self-assessment of adequacy of understanding • Difficulty recalling and applying new knowledge.	• Summarize, • Rehearse/Practice, • Self question/test self, • Self-reinforce with rewards.

Summary

The purpose of the CampusReader is to support readers struggling with comprehension and retention subsequent to an acquired brain injury. To ground the development of this intervention, four pertinent models (three specific to reading and one specific to the cognitive processes fundamental to reading comprehension) were reviewed that provide insights at different grains of analysis and from different perspectives. From the broadest perspective, the interaction between reader, activity, text and context is considered through the RAND's heuristic for thinking about reading comprehension. Moving to reading processes occurring within the reader, an interactive-activation model was described to provide an overall view of how reading occurs and to specifically highlight that the focus of the CampusReader project is on reading comprehension. Next, the specific reading comprehension processes relevant to construction of mental representations was discussed to help ground anticipated points of disruption for the CampusReader population, and examples of strategy interventions. Finally, a model explaining the roles of working memory, retrieval and encoding processes critical for comprehension and retention was described as these processes are particularly relevant to the aims and target population of the CampusReader project. With a theoretical basis established, the anticipated disruptions in the reading process experienced by individuals with mild acquired brain injury were outlined, with related possible compensatory strategies introduced.

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