Just and carpenter model of reading

 Reading is a complex skill that includes orchestrating a number of components. Researchers often talk about reading models when talking about only one aspect of the reading process (for example, word identification models are often referred to as reading models). Here we look at known models that are designed to account for (1) word identification, (2) syntactical parsing, (3) discourse representations and (4) as certain aspects of language processing (e.g. word identification), combined with other limitations (e.g. limited visual acuity, saccadic error, etc.), reader guidance. Unfortunately, these different models, relating to specific aspects of the reading process, rarely relate to models on other aspects of reading. For example, word identification models rarely involve eye motion control models, and vice versa. While this may be unfortunate in some ways, it is understandable in other respects because reading itself is a very complex process. We discuss prototype models of aspects of the reading process in the order mentioned above. We do not consider all possible models, but rather focus on those that we consider to be representative and most recognized. Reading is a complex skill that is a prerequisite for success in our society, where a lot of information is transmitted in writing. Reading is also a process that has caught the attention of many cognitive scientists because many fundamental cognitive processes are involved in reading. As Huey noted (1908) in his classic quote: And therefore to fully analyze what we do when we read would be almost the pinnacle of the achievements of a psychologist, for it would describe so many of the most complex works of the human mind, as well as to unravel the convoluted history of the most remarkable particular play that civilization has learned in its entire history. In a chapter on reading at the Foundations for Cognitive Science (Posner, 1989), Polltacek and Rayner (1989) identified ten central questions regarding reading the central interest in cognitive scientists. These questions were: How are written words identified? How does the oral language system interact with word identification and reading? Are words identified differently in the text than in isolation? When reading, the eyes move around the page. How this process answers to the above questions? How does the reader go beyond the meaning of individual words? (For example, how are the sentences disassembled, the literal value of the sentence is built, anaphoric connections are established, conclusions are drawn and so on?) What is the final reading product? (That is, what new mental structures are formed or preserved as a result of reading?) How does the ability to read develop? How can we characterize individual differences between readers in the same culture and differences in readers in different cultures? How can we characterize and correct reading irregularities? Can we improve normal reading (e.g., is it possible to read quickly)? These ten questions remain very relevant 20 years later, and indeed, they are the focus of textbooks on the psychology of reading (Rayner and Pollatsek, 1989; Rayner, Pollacek, Ashby, and Clifton, 2010). And while the questions remain very relevant and are the focus of a significant amount of ongoing empirical research, our goal here is to focus on another aspect of reading that is central to cognitive science. In particular, we will focus on developing different models (often computationally implemented) that describe some components of the reading process. It is instructive that there is not yet a complete model that will report on all the different components of reading1. Rather, over the past 20 to 30 years, models have emerged to take into account some specific aspects of the reading process. So, as we review below, there are models that make up (1) the definition of words, (2) syntactical parsing, (3) discourse views, and (4) how certain aspects of language processing (e.g. word identification) are combined with other limitations (e.g. limited visual acuity, saccadic error, etc.), guide readers to the eye. Unfortunately, these different models, relating to specific aspects of the reading process, rarely relate to models on other aspects of reading. For example, word identification models are rarely in contact with eye motion control models, and vice versa (although the latter type of model may be more in contact with the former type of model than vice versa; for example, see Reilly and Radach, 2006). While this may be unfortunate in some ways, it is understandable in other respects because, as we suggested, reading itself is a very complex process. We'll discuss the prototypes of aspects of the reading process in the order mentioned above. Our goal will not be to consider all possible models, but to focus on those that we consider to be representative and most highly recognized (with all due apologies to the architects of the models we are not focused on). (To better review existing reading models and attempt to integrate them into a single structure, what's going on is happening reading, see Reichl, 2010a). Typically, for many of these models, there are two central examples that make very different theoretical assumptions and that have triggered a significant empirical work. Our goal will be to clarify the nature of these assumptions and how patterns differ, and how these differences have helped inform our understanding of what is happening in the minds of readers. Over the past 30 years, numerous word identification models have been proposed, including Interactive Activation (McClelland and Rumelhart, 1981), Activation-Verification (Paap, Newsom, McDonald, Schwaneveldt, 1982), Multiple Levels (Norris, 1994), Multiple Reading (Granger and Jacobs, 1996), Multi-Stein Memory (Ans, Carbonnel, th Valdois, 1998), Connectionist Dual-Process (Sorzi, Houghton, Butterworth, 1998), and Bayesian Reader (Norris, 2006) models. However, the two models that received the most attention and motivated most of the studies are the Double Route Cascade (DRC) model (Coltheart, Rastle, Perry, Langdon, Siegler, 2001) and various parallel distributed processing or binding versions of what became known as the Triangle Model (Harm and Seidenberg, 1999, 2004; Plaut, McClelland, Seidenberg, Patterson, 1996; Seidenberg and McClelland, 1989). While these models are often referred to by their designers (as well as others in the field) as reading models, they are indeed models of reading out loud or what happens when identifying individual words displayed in isolation and therefore are not models of reading per se. Like most models to be discussed, they are fully implemented as computer programs that can be used to simulate tasks that have been used to study the identification of words (such as a lexical solution) and various phenomena (such as the word frequency effects) that have been used to draw conclusions about cognitive processes and perceptions that are involved in the identification of printed words (Taft, 1991). These models also share the basic assumption that bottom-up information, in the form of orthographic input, interacts with lexical knowledge to obtain the pronunciation of words and/or meanings. Here we will focus on DRC and model triangles, providing brief descriptions of models and how they differ. We will focus on these two models because they provide a contrasting framework to explain the two most well-known theoretical points of view during the ongoing discussion of how words are identified and presented in the mental lexicon. The discussion focused on whether the definition of words was guided by linguistic rules that were used to access the pronunciation of a word and/or the meaning of its atography, or whether the process was more accurately described as one in which types of lexical information provide reciprocal soft restrictions on and/or the meanings generated by word identification. The DRC model is more consistent with the previous viewpoint, while the triangle models are more in line with the latter view. There are two fundamental assumptions in the DRC model (Coltheart et al., 2001). First, the pronunciation of a word can be generated in two ways by applying graphema to the phoneme of correspondence rules that convert individual graphems (e.g. letters) of the word into appropriate phonological representations (i.e. phonemes), and through a more direct display of the spelling of the word to its pronunciation. Thus, the model refers to the dual-route model class (Carr and Pollatsek, 1985) in the sense that the pronunciation of a word can be generated using specific language rules that determine how individual graphems are pronounced for the pronunciation assembly, or in a more direct manner, extracting the pronunciation of the entire word directly from the lexicon. The second fundamental assumption of the DRC model refers to the nature of lexical representations: According to the model, both ontographic and phonological forms of words are presented holistically as discrete processing units in the lexicon, so that known words can be uttered by displaying the word graphem on the retographic unit, which provides the best matches, and then using an attographic block to directly activate that unit. However, unlike other dual-route models, the collected and direct routes work side-by-side in the DRC model, with the pronunciation of any word in most cases determined jointly by the products of both routes. Because activation spreads more effectively among representative units of common words, frequent words are pronounced faster and more accurately than rare words. And because the collected and direct routes work in parallel, words with regular pronunciation are pronounced faster and more accurate than irregular words, because these two routes cooperate to ensure the reliable pronunciation of ordinary words, but not irregular words. As mentioned, two main assumptions of different models of the triangle (Harm s Seidenberg, 1999, 2004; Plaut et al., 1996; Seidenberg and McClelland, 1989) are completely opposite to the DRC model. First, according to the triangle models, the pronunciation of the word is generated by spreading the activation from the computational units representing the athographic input along the connections with other units representing the phonological output. Thus, in stark contrast to the DRC model, the knowledge that allows the reader to identify printed words is contained in a single set of inputs to the output connections, so that the total amount of knowledge affects the pronunciation of the pronunciation and every word that is generated. Secondly, lexical information is presented in a distributed way in triangular models, with the dominant variants suggesting that the anthographic input and phonological output are presented not by specific units per se, but by specific models of distributed activity between units. Thus, in stark contrast to the DRC model, triangle models do not assume that lexical information is represented by discrete processing units in the lexicon, but instead assumes that such information is contained in connections that mediate between the atographic input and the phonological output. And because the strengths of these connections are learned through repeated experiences with words, triangle models predict that frequent words are pronounced faster and more accurately than rare words. Similarly, since the connections that are intermediaries in the pronunciation of ordinary words are more consistent with each other than those that are intermediaries in the pronunciation of irregular words, regular words are pronounced more quickly and accurately than irregular words. As mentioned, both THE DRC and triangle models (as well as some of the models we haven't discussed) make predictions about the errors of answers, errors, and types of errors that are observed in tasks such as naming and lexical solutions. Models also explain the large number of important benchmarks that have been recorded in experiments that have used these tasks, such as the conclusion that frequent words are identified faster than rare words (Forster and Camera, 1973), and that this frequency effect is usually greater for words with irregular pronunciation (e.g. words like pint, colonel, and yacht) than with regular pronunciations (Seidenberg, Waters, Barnes, Tanenhouse, 1984). Finally, models report on patterns of behavioral deficits that are commonly observed with different types of acquired dyslexia. For example, the DRC model argues that the phonological dyslexia, which can be characterized by the difficulty of pronunciation of a novel (i.e. unknown) words and non-words (i.e. spoken lines of a letter as a burk), but not known words (Coltheart, 1996), stems from selective damage to the collected route, which prevents the use of grapheme-phonem correspondence rules to create the correct pronunciation of the letter. The DRC model also suggests that superficial dyslexia, which can be characterized by the complexity of pronunciations of irregular words, but not ordinary words (Patterson, Marshall, and Coltheart, 1985), is the result of selective damage to the direct route, so that elements can only be pronounced through the rules of graphema correspondence to the phoneme. Triangle models offer a slightly different phonological score This reflects the damage to some of the ortography to phonology compounds, so that only words that have already been studied can be uttered, with little ability to generalize through words to pronounce new words or non-words. Triangle models also offer an alternative account of superficial dyslexia: This occurs when orthographs to phonology compounds become overly specialized for the pronunciation of consecutive words, because the pronunciation of incompatible words is too dependent on a semantic system that is selectively damaged. Thus, while DRC and triangle models are able to explain patterns of behavioral deficits that are observed with both types of dyslexia, both models do so very differently. Given this, along with the fact that both models explain a number of other findings from the literature on word identification, it is perhaps not too surprising that the debate about which model provides a more accurate and useful description of what happens in the mind of the reader when c/it defines the printed word still continues one (e.g. see Andrews, 2007). We suspect that future efforts to understand the cognitive processes and perceptions associated with the definition of words while reading may benefit from a more thorough examination of how lexical processing limits and is constrained by other reading components. Now we're going to turn to one of these other components of integrating the meanings of individual words to build the meanings of whole sentences. As with word identification models, there are many existing sentence-level processing models that explain how linguistic structures and limitations (such as syntax) guide the construction of views that are necessary to understand individual proposals. Thus, these models seem to take as input from the bottom-up the meanings of individual words, which are provided by the types of word identification models that were considered in the previous section. These models can be categorized into three broad categories to include different models of the garden track (Ferreira and Clifton, 1986; Fraser, 1977, 1987, 1990; Fraser and Clifton, 1996; Fraser and Fodor, 1978; Fraser and Rayner, 1982; Rayner, Carlson, Fraser, 1983), Models Based On Limits (Jurafsky, 1996; McDonald, Perlmutter, Seidenberg, 1994; Macrae, Spivey-Knowleton, Tanenhouse, 1998; Spivey and Tanenhouse, 1998; Tanenhaus and Trueswell, 1995) and various models implemented using connected frames (Elman, 1991; McClelland, St. John, and Taraban, 1989; Tabor, Giuliano, Tanenhouse, 1997). Since the first two of these groups of models received the most attention, and because the basic assumptions of the different communication models largely coincide with those of the limitations on the models, we will limit our discussion and the model-based restrictions below. Basic theoretical theoretical between these two classes of models relates to the number of priorities given to syntax processing during reading. Garden walkway models (Ferreira and Clifton, 1986; Fraser, 1977, 1987, 1990; Fraser and Clifton, 1996; Fraser and Rayner, 1982; Rayner et al., 1983) attach a logical meaning to the grammatical structure of the sentence. These models show that the reader first builds a single grammatical analysis of the sentence and then interprets it, reviewing the analysis if necessary. Although the construction of a single analysis is not an obligatory part of the model that gives grammar a logical priority in understanding the sentence (Gibson, 1991, 1998), serial depth models first (Frazier, 1995) assume that one analysis is selected and that the initial analysis is simply the first one to be completed (see Fraser, 1987; Fraser and Clifton, 1996). Although technically none of these models have actually been implemented within the formal computational types of linguistic analyses that are described, are accountable for implementation in the production system (Newell, 1990), in which productions (i.e. if 〈X〉 - then 〈Y〉 rules) determine the cognitive operations that direct syntax analysis (for example, if 〈smois - noun〉 - then〈 y noun〉 One of the recent demonstrations of how such a syntaxic parser can be implemented, is Lewis and Vasishe (2005), who used the architecture of the ACT-R production system (Anderson s Lebiere, 1998) to simulate syntax operations involved in the processing of proposals. MacDonald, Perlmutter, Seidenberg, 1994; Macrae, Spivey-Knowlton, Tanenhouse, 1998; Spivey and Tanenhaus, 1998; Tanenhaus and Truswell, 1995), believe that the grammatical structure is just one of the many interacting limitations on the interpretation of the sentence. based on limitations, the grammatical structure may have significant weight in determining the interpretation of a sentence, but it does not take precedence over factors such as plausibility or contextual limitation (or appropriateness). For example, using the competition integration framework, developed by Spivey-Knowlton (1996), McRae et al (1998) modeled models of self-reading time on abbreviated relative sentences (e.g., a fraudster/cop arrested by a detective was guilty of taking bribes.), in which the thematic role of the original noun phrase (i.e. the fraudster versus the policeman) had semantic traits that were more compatible with the role of the patient against the agent (respectively). The restriction-based model used different types of information, such as the goodness of the thematic role of the original noun, and the bias to interpret the initial phrase as the primary compared to a smaller relative, etc., to predict quality reading time models over a variety of different interests (e.g., arrest of a detective, etc.). To make these predictions, different types of information spread the activation through the compounds to support each of the two possible interpretations of the sentence, so that after a series of processing cycles the model eventually settled into a state that corresponded to one of the two interpretations (i.e., which is most consistent with all different types of information). Both classes of models try to explain the patterns of reading time that are observed in self-reading and eye movement experiments, when readers are faced with sentences containing a syntactical structure of varying complexity. A classic example involves sentences containing structural ambiguity (such as a horse racing the tempo of a shed dropped.), which are often interpreted incorrectly during the first passage through the sentence. The goal is to explain why such misanalysis occurs and the process by which such misanalyses are restored so that readers can build a correct interpretation of the sentence. Perhaps because of their conceptual transparency, serial, deep-seated models stimulated many early studies, including many experiments that gave relatively strong support to the hypothesis that a single sentence analysis is usually calculated (Ferreira and Clifton, 1986; Fraser and Rayner, 1982; Rayner et al, 1983; Rayner and Fraser, 1987). However, many follow-up studies have been developed to show that non-grammatical factors can influence difficulty understanding sentences, even obscuring or eliminating the obvious contribution of grammatical factors (see Clifton and Duffy, 2001; and Rayner and Clifton, 2002, for reviews). As Clifton, Traxler, Mohamed, Williams, Morris, and Rayner (2003) noted, it seems that many cognitive scientists (especially cognitive psychologists) judge that limitations-based models have spent the day. Several factors seem to contribute to this judgement. First, restrictive models were introduced, often in communication models (McRae et al., 1998; Spivey and Tanenhaus, 1998), while the garden track model does not have 2. Second, cognitive psychologists are extremely cautious about basing cognitive processes on grammatical rules, which seem to change frequently with seemingly arbitrary theoretical changes in linguistics. Thirdly, some results provide rather dramatic evidence that the factors of meaning and plausibility can completely override the grammatical factors that take precedence in the deep-first model of analysis of proposals. One of the most convincing and frequently cited examples of the meaning and plausibility of information redefining grammatical factors is the trueswell, Tanenhaus and Garnsey (1994) study, which followed a classic study and Clifton (1986). They claimed to show that readers use semantic information to avoid avoiding More recently, Clifton et al (2003) used incentives from Trueswell et al and presented evidence they took to be more compatible with the serial, depth of the first models of parsing. At the moment both types of models have empirical support, but there are also studies that are difficult to reconcile with any point of view. While the garden path and limited-satisfaction models have given a big boost to research on the analysis of proposals over the past 25 years, other proposals have emerged recently.3 The one that has already been mentioned is the model of Lewis and Vasist (2005). This model tries to incorporate the computational model of syntax into the broader framework of existing cognitive architecture (ACT-R; Anderson and Lebier, 1998). While it is probably too early to assess the usefulness of this approach, we suspect that, considering how the various components of reading relate to both cognitive architecture and many other reading requirements, rapid progress could be made in identifying limitations of existing models, as well as identifying areas of residual ignorance. We'll get back to those ideas in the final section of this article. Finally, despite progress in modeling the processing of proposals, all the models that have been developed to date suffer from the same limitations that they generate predictions about reading time by converting some arbitrary processing complexity indicators (e.g., the number of processing cycles required to have the network settled into one interpretation of the proposal; McRae et al., 1998) for arbitrary text regions (e.g. a few word sentences). Thus, unlike several models that will be discussed later (in the section on eye motion control models), sentence processing models do not make direct predictions about the time needed to process significant units (e.g. morphemes, words, phrase structures) in real time units. As we have suggested before, we suspect that these limitations can be addressed by considering how the processing of proposals may be related to other reading components. Now we will turn to one of these components of the discourse processing, or the process of connecting the meanings of two or more sentences to create a common meaning of the text. Unlike the models discussed in previous sections, the models that have been proposed to explain the handling of discourse are more difficult to categorize into groups that define opposing positions on some central theoretical question4. Instead, models tend to describe certain aspects of processes and views that are needed to connect the meanings of individual sentences to more global views that support text understanding. In this way, they can be seen as notoriously blind men feeling elephant, with each model describing the description of aspect of discourse processing, but none of the models does it in a way that is complete. However, these models have a general view that they are based on representations that are presumably provided by the types of word identification and sentence processing models that have been considered in previous sections, using these representations at the word and sentence level as bottom-up inputs to create even larger representations of discourse. Examples of these discourse processing models include Building-Integration (Kentsh and Van Dyck, 1978), Situational Space (Golden and Rumelhart, 1993), Landscape (Van den Brooke, Risden, Fletcher, th Thurow, 1996), Resonance (Myers and O'Brien, 1998), and Distributed Situational Spaces (Frank, Koppen, Noordman, No Vonk, 2003) models, along with several binder and production system discourse processing models (e.g. Goldman and Varma, 1995; Langston , Trabasso, Magiano, 1999; St. John, 1992). In this section we will focus on just one of these models to illustrate a few important aspects of discourse processing that need to be explained by any complete reading model. This discourse processing model is the Building-Integration (CI) model, which was originally developed by Kinch and van Dyck (1978) and subsequently modified in subsequent incarnations (e.g. Kintsch, 1988, 1998; Schmalhofer, McDaniel, Keefe, 2002). The CI model assumes that the reader generates a sentence or meaning based on the presentation of the text in two successive processing stages. In the first phase of construction, the meanings of individual words are used in conjunction with syntax operations to create a text base or literal interpretation of the text. The information contained in the text database also triggers the search for additional related information from the shemath in the long-term memory. Together, this information forms a free associative network of sentences (i.e. elementary units of meaning consisting of a predicate and one 〈 or several arguments; for example, the fall〉 astress〉), which represents the meaning of the text and any conclusions that can be drawn from the text. This construction phase is done on a single phrase or sentence at a time, with the total number of proposals that can be actively supported at any given time limited by the ability of working memory, and with the strengths of associations that are formed between any couple of sentences is a function of how long sentences are actively maintained together. Finally, in the next phase of integration, the activation supporting the proposals is once again normalized in processing cycles in order to strengthen the links between important proposals (i.e. proposals that are associated with many others and thus are central to the meaning of the text), while associations between less proposals are weakened. This integration phase minimizes or eliminates text inconsistencies and/or information that is less important to the central meaning of the text. The CI model described accurately predicts what types of information that readers will remember when reading a passage of text, including the types of resumes that people provide text, which sentences are more important and therefore more likely to remember how this review changes over time and forgetting, and the types of information that readers are likely to enter in trying to understand the text. The latter finding is related to the types of conclusions that people seem to make while reading. The CI model explains two important types of conclusions (Schmalhofer et al., 2002). The first are forward or predictive conclusions that allow the reader to anticipate events or results that were not clearly stated in the text. Using an example taken from Schmalhofer et al., after reading the sentence Director and cameraman were preparing to shoot a close-up of the actress on the edge of the roof of the fourteenth building, when suddenly the actress fell., it can be concluded that the actress died. The second type of conclusion allows the reader to maintain consistency between events in the text and is called backward or intermediate conclusions. Having read the previous example of the proposal, we can draw an interim conclusion that the actress died after reading the verdict: Her orphaned daughters sued the director and the studio for negligence. Schmalhofer et al. modelling has shown that the CI model provides a natural accounting of both types of findings, since the normal process of generating text related information from the shemath during the model construction phase is sufficiently liberal to obtain the types of associations between sentences that are needed to draw both reverse and reverse conclusions. In their simulations, Schmalhofer et al. showed that the CI model is capable of mimicking the priming effects that were observed when Keith and McDaniel (1993) had participants read short passages of text containing sentences like previous examples, and then tested their participants with a probe of the word as dead; the model predicted the effects of the primer, indicating two types of conclusions in the experiment, as well as whether there will be a primer when the key phrase (... the actress fell.) additional text materials followed. Such demonstrations, along with many others (e.g. Kintsch, 1998), demonstrate the overall individuality of the PI model and its ability to take into account the various phenomena of discourse processing. Finally, it should be emphasized that, like the CI model, other discourse processing models try to describe how the text is used to build views using the literal meaning of text and information that is already in memory (i.e. the facts contained in the shemat) for the purpose of understanding and memorizing the text. Thus, the models are designed to make clear predictions about reading understanding (e.g., whether readers notice textual inconsistencies), the types of conclusions people make when reading a text, and the amount and type of information that is subsequently memorized. Models are limited in the fact that they usually say nothing about online reading, making a few predictions about the time of the course reading. Such predictions are important for the final models that we will discuss models that determine how different reading components (such as word identification) combined with general perception, cognitive and motor limitations determine the moment to the moment the readers move through text. These models are most often described as eye motion control models when reading, and so they determine how top-down limitations (e.g. lexical representations) interact with the extraction of visual information from the bottom up (e.g. information about the length of the printed word) to create patterns of eye movements that are observed when people read text. There are now a large number of eye motion control models in reading. The development of such models was dictated by the appearance of the E-Reader model (Reichle, Pollatsek, Fisher, s Rayner, 1998). Although there were previous verbal (Morrison, 1984; O'Regan, 1990, 1992; Rayner and Pollacek, 1989) and realized models (e.g., Just s Carpenter, 1980; Riley, 1993; Riley and O'Regan, 1998; Suppes, 1990; For a review, see Reichle, Rayner, Pollacek, 2003), who tried to document aspects of eye movement in reading, E-I Reader clearly stimulated the development of a number of competing models, of which SWIFT (Engbert, Nuthmann, Richter, and Kliegl, 2005) is generally regarded as the main competitor. Other models include Mr. Chips (Legge, Klitz, th Tang, 1997)5, EMMA (Salvucci, 2001), SERIF (McDonald, Carpenter, th Shilcock, 2005), Glenmore Reilly (and Radach, 2006), SHARE (Feng, 2006), and competition-interaction model (Yang, 2006). All of these models are fully implemented, but they differ in a number of dimensions. For example, while Mr. Chips is the ideal type of observer model in the sense that he tries to simulate optimal performance with an initial set of psychological, physiological and task constraints, while each of the other models tries to explain the actual performance of human readers. Other important aspects include the determinants of when the eyes move from one word to another, and the nature of the distribution of attention. For example, in E-I Reader and EMMA, the completion of lexical processing basically determines when the eyes move while most other models believe that the autonomous timer largely determines when the eyes move, if saccadic programming is not inhibited by the cognitive complexity of processing. Similarly, models such as E-I Reader and EMMA believe that attention stands out consistently, only one word at a time, so that the lexical processing of the word n'1 does not begin until the meaning of the word n. In contrast, models such as SWIFT and Glenmore are believed to be paying attention in parallel (so that several words can be defined in parallel) and models of the model Such as SERIF, SHARE and the competition model, it is believed that attention plays little or all of a role in guiding the movements of readers' eyes. Due to space constraints, only E-I Reader and SWIFT models will be discussed here (for a review of these models, see the 2006 special issue of Cognitive Systems Research). In fact, the E-I Reader model presents such models, with the original versions discussed in Reichle et al. (1998) and subsequent versions presented by Reichle et al. (2003), Rainer, Ashby, Reichl and Pollacec (2004), as well as Pollacek, Reichl and Rayner (2006). In all of these versions of the model, the early stage of lexical processing is an engine that controls eye movements while reading. This early stage of lexical processing is called dating verification, and it is assumed that it corresponds to a point during word identification, when it is safe to start programming the saccada for the next word (i.e. initiating programming sooner or later will cause the eyes to move too early or too late and thus make reading less effective; Reichl and Laurent, 2006). The next stage of lexical processing, called the completion of lexical access, is a signal to change attention to the next word. Thus, the initiation of saccadic programs is separated from attention shift, with the latter being done (as mentioned) in a strictly serial manner (Reichle, 2010b). The rest of the model's assumptions are directly related to saccadic programming. First, saccad programming is completed in two stages: the initial stage of the labile, which is to be cancelled by initiating subsequent sacdad programs, and then the unrelenting stage, which, if completed, leads to a mandatory saccada. The second assumption is that saccades are always directed to the centers of words, but due to a systematic and accidental engine error often overestimating or exceeding the intended targets, resulting in the Gaussian fixation of the distribution site. The final assumption is that cases involving a large saccade error often lead (in a probabilistic manner) to the automatic refixation of saccades; these corrective saccades move quickly to a better viewing location (i.e. closer to the target word center) to support faster lexical processing. Finally, the most The model version (E-I Reader 10; Reichl, Warren, O'Connell, 2009) has been expanded to account for a higher order (i.e. post-lexical) effect of language processing on eye movements while reading. This model was used to simulate various control findings, as reported in eye movement experiments (Rayner, 1998, 2009), including the effects of low-level restrictions on the oculomotor (e.g. distribution of landing sites; McConkie, Kerr, Reddix, Ash, 1988), the influence of lexical variables (e.g., word frequency effects; Iniff and Rayner, 1986; Rayner and Duffy, 1986; Schilling, Rayner, Chumbley, 1998) and the influence of higher-level linguistic variables (e.g. Violations of semantic plausibility; Rayner, Warren, Juhash, and Liversage, 2004; Warren and McConnell, 2007). The model has also been expanded to mimic the Chinese language (Rayner, Lee, Pollacek, 2007), French (Miellet, Sparrow, Sereno, 2007), and older readers (Rayner, Reichl, Stroud, Williams, Pollacek, 2006), as well as a number of other phenomena related to reading (e.g., lexical ambiguity of the resolution; Reichl, Pollacek, Rayner, 2007). (For a full review of the various versions of the E-I Reader and the issues that have been resolved with the model, see Reichle, 2010b.) Although the main components of the SWIFT model also remained fairly constant at various points (see Engbert and Cligl, 2001; Engbert, Cligl, Longtin, 2004; Engbert, Longtin, Clygle, 2002; Richter, Engbert, Kliegl, 2006), the model has also grown in the theoretical realm, being used to imitate older readers (Laubrock, Kliegl, and Engbert, 2006) and tasks such as visual search (Trukenbrod and Engbert, 2007) and z-string (reading and Engbert , 2009). There are two main assumptions of the model. First, attention stands out as a gradient to support the lexical processing of two or more words. Second, immediate decisions about when to move your eyes from one viewing location to another are determined by a random timer that triggers the initiation of saccadic programming at random intervals; variables such as the duration of word-fixing are only indirectly by inhibiting random timers, delaying the initiation of saccadic programming, and thereby increasing the duration of fixation. (The rest of the assumptions about saccade programming and execution are almost identical to E-I Reader.) In the latest version of the SWIFT model, this saccadic braking is delayed for a considerable amount of time to meet the hypothesis that higher level (e.g. cortical) fixation control is relatively slow, intervening only occasionally to modulate the duration of the fixation (Findlay s Walker, 1999). Like E-Reader, SWIFT can take into account the full range of reference phenomena that have been used to evaluate models (Reichle et al., 2003). However, until now, this model has not been explicitly used to simulate higher-level language processing effects, but has been used to explain how fairly low-level variables (e.g. visual acuity, oculomotor limitations, lexical variables, etc.) affect the movements of readers' eyes. We suspect that recent efforts to develop the E-I Reader as a basis for overcoming a higher level of language processing to control eye movement will force SWIFT designers to be more explicit about how their model explains the interface between language processing and eye movement. We will return to this issue in the final section of this article. As mentioned, the cognitive processes that support reading are varied and complex. This is undoubtedly the reason why, to date, efforts to develop computational reading models have largely focused on explaining only one or two components of reading processing (e.g., how printed words are identified), with little effort to explain how these components interact with other processes that are important for reading (e.g. attention distribution). We suspect that while this strategy may have proved effective in allowing cognitive scientists to focus on their specific problems, the approach may be limited in that it tends to provide a narrow view of what is really going on in the minds of readers. An alternative view of the role computational models play in cognitive science is that it is better to develop large-scale models of overall cognitive architecture than to develop smaller models of specific cognitive tasks (Anderson s Lebiere, 1998; Just and Carpenter, 1980; Newell, 1990; Newell, Rosenbloom, and Laird, 1989; Rumelhart, 1989). The argument for this view is that by adopting the first approach, one is forced to consider the domain's general limitations that apply to all cognitive tasks, thereby forcing model designers to see the big picture. If we take Huey's assertion (1908) that understanding reading would be to understand the most complex works of the human mind, it is not unreasonable to advocate a more integrative approach to reading modeling, in which architecture reading models force theorists to explicitly state how the assumptions of their models fit into the broader structure of what is explained. For example, word identification model designers will have to specify how words are identified by two or more fixations (i.e. from different viewing sites) and taking into account the limitations of human visual acuity. Another specific example of the types of issues that can be addressed with this more integrative approach to modeling is an ongoing debate about the nature of the character Distribution during reading (i.e. whether it is serial or parallel); careful consideration of existing word identification models points to the conceptual challenges faced by eye motion management models (e.g. SWIFT and Glenmore) that stick out attention gradients and parallel lexical processing of two or more words, including, for example, the potential need for multiple lexicons (Reichle, Liversedge, Pollatsek, s Rayner, 2009). While the task of developing more integrated computational reading models will undoubtedly be challenging, it is easy to imagine how such models can be used to gain an important new understanding of the nature of reading and human cognition (e.g. how the time of syntax parsing affects the construction of presentation discourse, how limitations of top-down sentences and discourse-level views can limit identity, etc.). Indeed, if we revise the ten questions that were posed at the beginning of this article, it is clear that all these questions (with the possible exception of the former) seem to suggest this type of more integrative approach.1Just and Carpenter (1980) portrayed their model as a comprehensive reading theory from the original eye fixations to understand and Rainer and Pollatsek (1989) presented the outlines of a more complete reading. However, both attempts were fairly tentative.2 It is interesting to note that Binder, Duffy and Rayner (2001) implemented a satisfaction restriction model that did not match the data they received.3B addition to the Lewis and Wasisht models (2005), these models include surprisal (Hale, 2001; Levi, 2008), race model (von Gompel, Pickering, Thrakler, 2001) and The Theory of Locality (Gibson, 1998). Some of these new models were linked more directly and tested by eye movement data (Boston, Hale, Patil, Clygle, Wasist, 2008; Demberg and Keller, 2008), and thus begin to build bridges between the models of disassembly and the model of eye movement control (see also Reichl et al., 2009).41 An important dimension on which the theoretical views of the discourse of processing differ in degree. in which readers of minimalists (McKoon and Ratcliff, 1992; Myers and O'Brien, 1998) and only generate conclusions when necessary, or builders (Graesser, Singer, Trabaso, 1994) who are constantly generating hypotheses and drawing conclusions.5Technically, Mr. Chips appeared before the E-I Reader, but it is the case that the latter model attracted more attention than the first (perhaps partly because Mr. Chips is the ideal model of the observer). Cross-referencesCOGSCI 067 - Computing models lexiconCOGSKI 071 - Eye tracking and language processingCOGSCI 093 - Processing models: LexiconCOGSCI 094 - Processing models: DiscourseCOGSCI 201 - processingDander JR, Lebyer C. Atomic Components of Thought. Mahwa, New Jersey: Erlbaum; 1998. Google Scientist Andrews S. From Ink to Ideas: Challenges and Disputes About Word Recognition and Reading. New York: Psychology Press; 2007. Google ScholarAns B, Carbonnel S, Valdua S. Linked multi-layered memory model for multi-complex word reading. Psychological review. 1998;105:678–723. (PubMed) (Google Fellow) Binder KS, Duffy SA, Rayner K. Influence thematic fit and context discourse on resolving syntax ambiguity. Diary of memory and language. 2001;44:297–324. (Google Fellow) Boston MF, Hale JT, Patil U, Kliegl R, Wasisht S. Spending Review as predictors of the complexity of reading: Assessment of potsdam verdict Corps. Research journal eye movement. 2008;2(1):1, 1–12. 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