Integrating Creativity and Reading: A Functional Approach

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Abstract

Reading has been studied for decades by a variety of cognitive disciplines, yet no theories exist which sufficiently describe and explain how people accomplish the complete task of reading real-world texts. In particular, a type of knowledge intensive reading known as *creative reading* has been largely ignored by the past research. We argue that creative reading is an aspect of practically all reading experiences; as a result, any theory which overlooks this will be insufficient. We have built on results from psychology, artificial intelligence, and education in order to produce a functional theory of the complete reading process. The overall framework describes the set of tasks necessary for reading to be performed. Within this framework, we have developed a theory of creative reading. The theory is implemented in the ISAAC (Integrated Story Analysis And Creativity) system, a reading system which reads science fiction stories.

Introduction

Researchers from psychology, education, and artificial intelligence have studied the process of reading for decades; however, while many theories have been proposed, none explained the complete process. In particular, *creative reading* has been largely ignored; while creativity is recognized as a central and crucial issue in reading, past language researchers have disregarded it. By analyzing existing evidence and reviewing proposed theories from psychology, artificial intelligence, and education, we have created a *functional theory* which can act as a framework for describing the complete range of cognitive tasks involved in reading. The framework is instantiated by building a computational model of the processes and knowledge that underlie the reading tasks. This approach allows us to investigate a broader set of reading issues than was possible in the past, namely the set of processes needed for creative reading to occur. Our focus is on the science fiction genre since these stories offer many opportunities for creative reading. We are implementing our theory of creative reading in the ISAAC (Integrated Story Analysis And Creativity) system.

Reading, creativity, and creative reading

Numerous terms have been proposed to describe what the layperson calls "reading," including *text understanding*, *narrative understanding*, *text comprehension* and *sentence processing*. Unfortunately, each of these terms represent research efforts which focus on only small parts of the overall task of reading, thereby carrying connotations which we wish to avoid. We, therefore, choose to use the common term *reading* to denote the process by which an agent translates an external, written representation of a text into an internal set of representations; these internal representations can then be used to explain elements of the text, to predict future events, or to support other reasoning tasks. This should be considered a working definition; while it captures a great deal of the cognitive aspects of reading, there may be areas in which it is either too broad or too narrow.

Our definition of creativity is also a working one. There are two facets to *creativity*: *creative invention* (e.g., Hofstadter & McGraw, 1993; Kolodner & Wills, 1993) is a directed, internal process by a cognitive agent which results in an artifact which is novel and useful; *creative understanding* is a directed, internal process by a cognitive agent which results in a useful understanding of a novel artifact. Finally, we can define *creative reading* as reading which includes novel concepts which the reader must creatively understand in order to comprehend the text. Active engagement of the text is a prerequisite for creative reading to occur; readers must attempt to incorporate the text into their own backgrounds.

In order to creatively read, a person must be a capable reader at a number of levels, from simple decoding of words into internal concepts to the active engagement of the text and building of complex mental worlds to model the textual elements. Education researchers have believed for decades that creative reading is a part of all successful reading experiences (see, for example, Harris & Sipay, 1990; Stoodt, 1989); recent work by Popov (1993) also shows the importance of creativity for reading comprehension. Our chosen genre of study, science fiction, is well-suited for research into creative reading. Most human readers will not have all of the concepts needed to understand a science fiction story, especially if they are first time readers of the genre. Consider the story, *Men Are Different*, shown in Figure 1. In order for most past "story understanding" systems to comprehend this story, all the proper concepts would need to be in memory at reading time. A system would need to know that Mankind was extinct, that Robots were intelligent, and so forth. Notice that these concepts are *false* outside the confines of this story (and possibly related science fiction tales). The story is not a simplification of the real world, it is a falsehood about the real world. Yet, human readers do not need to possess all the "correct" concepts *a priori* when reading a story. Instead, most readers of science fiction have no problem suspending their disbelief of these novel concepts and attempting to understand them within the world of the story. Our goal is to produce a theory which is able explain this ability and to embody it in a computational model which could produce similar behavior.

I'm an archaeologist, and Men are my business. Just the same, I wonder if we'll ever find out about Men—I mean *really* find out what made Man different from us Robots—by digging around on the dead planets. You see, I lived with a Man once, and I know it isn't as simple as they told us back in school.

We have a few records, of course, and Robots like me are filling in some of the gaps, but I think now that we aren't really getting anywhere. We know, or at least the historians say we know, that Men came from a planet called Earth. We know, too, that they rode out bravely from star to star; and wherever they stopped, they left colonies—Men, Robots, and sometimes both—against their return. But they never came back.

Those were the shining days of the world. But are we so old now? Men had a bright flame—the old word is "divine," I think—that flung them far across the night skies, and we have lost the strands of the web they wove.

Our scientists tell us that Men were very much like us—and the skeleton of a Man is, to be sure, almost the same as the skeleton of a Robot, except that it's made of some calcium compound instead of titanium. Just the same, there are other differences.

It was on my last field trip, to one of the inner planets, that I met the Man. He must have been the last Man in this system, and he'd forgotten how to talk—he'd been alone so long. I planned to to bring him back with me. Something happened to him, though.

One day, for no reason at all, he complained of the heat. I checked his temperature and decided that his thermostat circuits were shot. I had a kit of field spares with me, and he was obviously out of order, so I went to work. I pushed the needle into his neck to operate the cut-off switch, and he stopped moving, just like a Robot. But when I opened him up he wasn't the same inside. And when I put him back together I couldn't get him running again. Then he sort of weathered away—and by the time I was ready to come home, about a year later, there was nothing left of him but bones. Yes, Men are indeed different.

Figure 1: *Men Are Different* (Bloch, 1963)

A functional theory of reading

To produce a *functional theory* of reading, we need to identify the *tasks* which various *processes* must perform in order to produce the behavior, the *knowledge* which the processes use, and the *control* mechanisms which coordinate the processes and results. We have identified six *supertasks* necessary for explaining the reading process (Figure 2). Supertasks are groups of conceptually similar tasks which interact to produce a particular form of understanding. The supertasks are:

- **sentence processing:** This supertask is responsible for low-level understanding, and includes tasks such as *pronoun reference*, *syntactic parsing*, and *lexical retrieval*. For example, in the second line of the last paragraph of *Men...*, a reader must retrieve meanings for the various words and determine who the "he" is referring to. Other tasks are *punctuation analysis* and *tense analysis*.

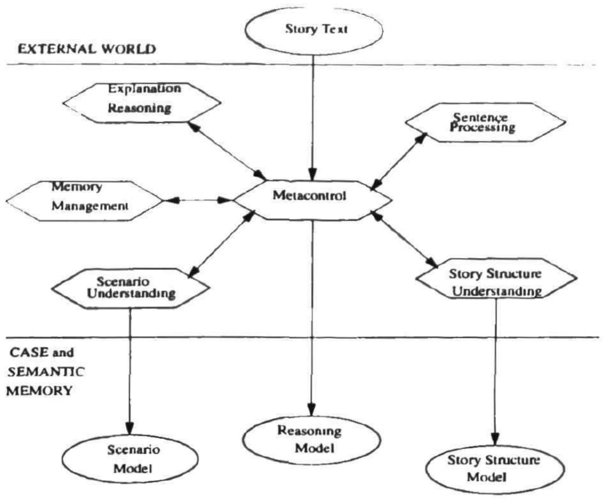

Figure 2: Functional model of reading

- **story structure understanding:** This supertask handles details which relate to story structure. Tasks include *character identification*, including protagonist and antagonist; *setting identification* (time and location); *plot description*, which builds a coherent summary of the story's plot; and *genre identification*, which identifies the text's style. This supertask is largely the result of the way in which reading is taught in Western culture (Smith, 1986).
- **scenario understanding:** The tasks making up the scenario understander are the *event parser*, which identifies agents, actions, states, objects, and locations within an episode; the *agent modeler*, which maintains descriptions of the agents, and tracks their goals, knowledge, and beliefs; the *action modeler*, which maintains descriptions of the acts with which the agents are involved; and the *device modeler*, which forms understandings of how various objects function.
- **explanation and reasoning:** This supertask performs high-level reasoning and learning. *Creative understanding* attempts to understand concepts which do not fit the reader's world view. *Interest management* controls the reader's level of interest in the story. *Belief management* manages the beliefs of the agents involved in the episode. Did the robot actually believe that the Man was capable of being turned off? If so, how did it arrive at this erroneous conclusion? The *explanation* task builds the inferences needed to connect the events of the story, enabling the reader to learn from the material. Finally, *metareasoning* reflects on the reader's actions during the reading process; this information is also used for learning.
- **memory management:** This supertask handles general memory storage and retrieval. It consists of *case building*, which constructs the various cases which result from reading; *memory retrieval*; and *memory storage*. Some of the memory event while reading *Men...* may be spontaneous; for example, the story may trigger memories of other stories which concern the extinction of humankind. Other memory processes will be more deliberate; while reading *Men...*, the reader might try to remember the last science fiction story they read written by Alan Bloch.

- **metacontrol:** Metacontrol integrates the other supertasks. It includes *focus control*, which manages the depth of reading based on interest and understanding; *time management*, which allows the reader to make decisions based on time resources; and *suspension of disbelief*, which enables a reader to accept a text which violates their world view. This last function is particularly important in the case of reading a story containing unfamiliar concepts. A reader of *Men...* knows that the story cannot be true. Mankind still exists, extensive space travel does not, and robots are merely mechanical tools. In order to understand the story, the reader must accept these unfamiliar ideas for the duration of the reading experience.

The supertasks were identified through functional analyses of reading processes, supported by evidence from psycholinguistics (e.g., Holbrook et al., 1992; van Dijk & Kintsch, 1983), reading comprehension (e.g., Black & Seifert, 1981; Graesser et al., 1991), story understanding (e.g., Ram, 1991; Rumelhart, 1977), memory (e.g., Anderson, 1974; Kolodner, 1984), and metacognition (e.g., Ram & Cox, 1994; Weinert, 1987).

The power of this modular, integrated approach is that each supertask directly supports all of the others. No single supertask can exist in a vacuum; rather, each relies on aspects of the processing being performed by the remaining ones. Furthermore, every task in the theory is situated with respect to the overall framework; this acts to focus the behavior of each with respect to the ultimate goal of reading a given text. Similarly, the entire reading act is situated in the real-world story context being dealt with, adding further focus to the supertasks. It is the synergy of the six supertasks in relation to the text which produces the behavior we call reading.

In addition to this modular breakdown of tasks, our theory makes use of *models* in order to provide crucial knowledge for comprehension. *Sentence models* provide the capability of dealing with different low-level structures, such as questions, declarative sentences, quotations, broken or interrupted speech, and sentence fragments. Next, *story structure models* include genre specific models, as well as models describing narrative types (such as first-person and third-person narratives). A similar idea has been proposed by Carpenter and Alterman (1993); in their model, case-based reasoning is used to control the reading process which "knows" how various text genres should be read (e.g., when confronted with a set of complex instructions, skim the first few pages looking for an enumerated list as these are important to instruction following). *Scenario models* explain different styles of agent interaction. These include various combinations of "social states" in communication; for example, the type of interactions one would expect to see between two close male friends would be very different from the type of interaction exhibited between a boss and an employee in a formal business setting. Several of these social relations can be seen in *Men Are Different*: the protagonist is a peer among the robot archaeologists, it was a student of the historians discussed in the story, and it was a researcher with respect to the experimental subject (the man). The reader's high-level reasoning is guided by the various *reasoning models*. These control how much explanation a reasoner may choose to do in a given scenario; e.g., if a person's car breaks down on the highway, do they immediately try to find help, reason and examine the immediate possible causes, or attempt to reason the problem through to completion? *Memory models* permit different types of memory access to occur; based on the type of material being read, a reasoner may request the construction of a careful memory of the material (e.g., studying for a midterm test) or request a more shallow memory be built (e.g., reading a cereal box for the list of ingredients). Finally, *metacontrol models* allow the reader to tailor reading patterns to a given situation. Is the material being read for pleasure, for study, or to kill time?

Creative understanding

Reading occurs when the six supertasks interact and make use of the reasoner's existing knowledge to translate a text representation into a set of internal representations. If the reader's knowledge is sufficient to comprehend the text, creative understanding is not needed. However, it is likely that at some point in the reading process, the reader will be faced with a concept that cannot be understood with existing knowledge. At this point, the *creative understanding process* must attempt to understand the novel concept. The algorithm is a four step cycle; each pass through the algorithm increases the potential for successful understanding. An overview of this process follows; for a more complete description see Moorman & Ram (1994).

1. During reading, internal representations of the text are being built and maintained. As each text phrase is decoded, the reader attempts to incorporate it into the existing structures. *Memory retrieval* occurs, with the new concept acting as a probe. If the concept already exists in memory, one of two things occurs. First, the concept may fit into the existing representations. If so, processing can continue. On the other hand, the concept may not fit; this is a signal that more in-depth understanding is needed.
2. It may be that the new concept *will* fit into the existing structures. Rather than a direct fit, however, an *analogy* (e.g., Falkenhainer, 1987; Gentner, 1989) may have to be derived, relating an existing concept (the *base*) to the new concept (*the target*). The algorithm examines the existing representation and checks to see if any of the concepts there can be related to the new concept. If such a relationship exists, reading continues.
3. If no relationship can be found, the algorithm attempts to force a relationship to exist. By using general background knowledge, the reader may be able create a concept which captures the essence of the original one or a generalization of the original concept. This is similar to analogy, but the *base* which is used to understand the new concept is dynamically created by the reasoner; we therefore call this mechanism *base-constructive analogy*.[1]
4. If the above steps have failed to produce an understanding, the creative understanding algorithm resorts to *problem reformulation*. It may be that the initially retrieved concept is not the one which should have been remembered. It may also be the case that a portion of the existing representations is flawed and is not useful to the current reasoning.

[1] While we are not the first to describe a cognitive process similar to this (e.g., Nersessian, 1992; Clement, 1989), we do not know of any models which implement it.

	Physical	Mental	Social	Emotional	Temporal
Agents	person	consciousness	boss	Ares	entropy
Actions	walking	thinking	selling	loving	getting closer to March
Objects	rock	idea	teacher-student relationship	hatred	second
States	young	lack of knowledge	public dishoner	being angry	early

Figure 3: Knowledge organization grid

Therefore, the algorithm reconsiders the retrieved concept, based on information contained within the story concept. This reformulated concept is then used to probe memory for potentially better responses than the original attempt.

Successful creative understanding may result in the reasoner undergoing *conceptual change* (Chi, 1993; Ram, 1993); that is, a concept may shift in the reasoner's knowledge system. If the reasoner possesses a useful ontology at the outset of a reading experience, this conceptual change can be used as a heuristic to guide the creative understanding process. There is an inherent danger with the creative understanding algorithm: at some point the algorithm will be so far removed from the original concept that understanding will move from being creative to being simply bizarre. To overcome this, some method of control is needed. Our theory's ontology places knowledge into a two-dimensional grid, as seen in Figure 3. If conceptual change leaves the concept in the same grid cell, it is unlikely to be bizarre. A movement along either axis is potentially more creative but also more bizarre. Finally, a conceptual change which transfers a concept along both axes is the most potentially creative and most potentially bizarre and should be approached with great care.

Implementation

The ISAAC system is currently able to read the story presented in Figure 1. ISAAC is built in Common Lisp and uses the KR frame package (Giuse, 1990) for knowledge representation and the COMPERE system (Holbrook et al., 1992) for the sentence processing supertask. ISAAC builds a detailed story structure model, a scenario model of the events, and a metareasoning model of its activities during the reading process. Figure 4 shows a portion of its understanding of *Men Are Different*.

As ISAAC begins reading, its default story structure model includes information that a text with a phrase and an agent prior to the first paragraph can be assumed to have an explicit title and author. Metacontrol, therefore, treats the stand-alone phrase *Men Are Different* as the title, and the agent *Alan Bloch* as the author. Next, the sentence processor parses the title phrase; it is recognized as an extended state declaration: ISAAC expects an object to be related to another object in a given way. Scenario understanding tags *Men* as the first object and *Different* as the relation. Metacontrol now expects

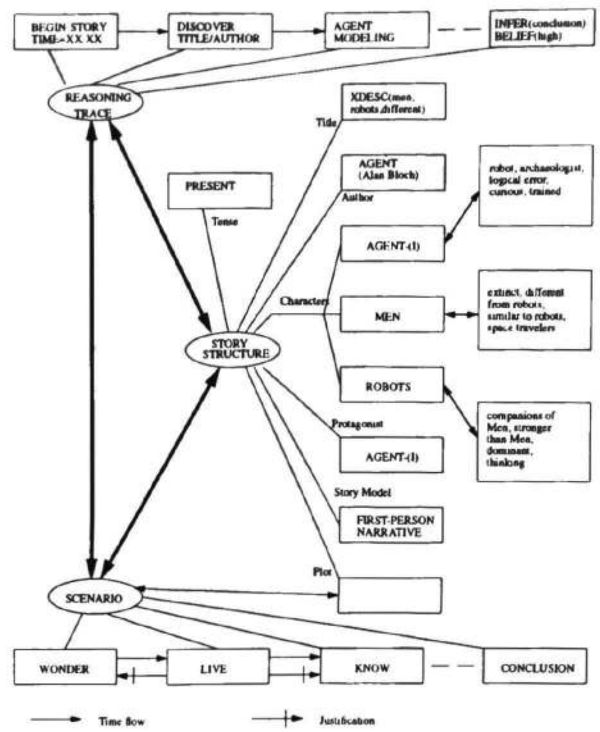

Figure 4: Partial view of ISAAC's understanding of *Men Are Different*

to find the second object. Since none is available, metacontrol decides, due to its knowledge of titles, that this is an important omission and expects to find the object in later text. Finally, various memory requests are generated. Metacontrol requests that the memory supertask store the title and author information, and a retrieval is performed to see if the system has either read this story before or read similar works. Since this is the first reading event, nothing is returned.

By the end of the first paragraph, ISAAC realizes that something is not quite right. ISAAC only knows about robots which are industrial machines. The robot in the story is very different from this. Metacontrol decides to suspend disbelief and creatively understand the concept of the story robot. Memory retrieval returns a concept of robot which is insufficient to explain the character, and an attempt at analogy fails since there are not enough relevant features (between the story robot and the robot from memory) which are similar. Next, ISAAC attempts to transfer the concept to a volitional domain (base-constructive analogy). This attempt is not successful since the concept of robot directly violates the concept of volition. Finally, ISAAC tries problem reformulation, changing from trying to understand the character as a robot to trying to understand it as a volitional agent. This results in the production of a merged concept containing elements of the robot concept and the best volitional agent the system can retrieve from memory—a man. The result is a man-like, intelligent, volitional robot. The new concept maintains many characteristics of the original robot—it is made of metal, resistant to damage, uses sensors and feedback as a control mechanism, and so on.

This concept is sufficient to understand the robot in the story, so ISAAC stores it in memory as a *story-robot*, a new kind of robot.

Skipping ahead to the last paragraph, we see that ISAAC must treat this as a "story-within-a-story." To appreciate the ending, the reader must have maintained a correct model of the narrator, including its beliefs and goals, in order to understand why the robot's mistake took place. ISAAC needs to perform a similar creative understanding task on the man in the story as it did on the robot narrator. In this case, the creative understanding arises from a need to understand why the robot narrator acted in the fashion that it did. As a result, ISAAC understands that the robot is seeing the man as more similar to itself than is warranted; this explains the logical error.

The key irony in the story can be seen as a dual shift within our knowledge organization grid. ISAAC is presented with a robot character which is acting as an *agent* rather than as a *physical object*. This is the first shift which must take place for ISAAC to "make sense" of the story. The twist ending occurs because the robot narrator decides to treat the Man, a *physical agent*, as a *physical object* and disassembles him with the intent of doing a field repair.

Related work

In addition to modeling the process of reading and creative understanding, our theory allows previous theories to be examined within a common framework. Past reading systems have not been greatly successful due to their insufficient coverage of the reading process. Early examples such as SAM and PAM (see chapters 5 and 7 in Schank & Riesbeck, 1981) were narrow attempts to handle what we call the scenario understanding supertask through scripts and plans. They did not try to benefit from the other supertasks we have identified; furthermore, they dealt with extremely short narratives. Dyer's BORIS (1983) was a more involved system which attempted to overcome the deficiencies of earlier ones by integrating the current theories of its day in order to perform "in-depth" reading. Unfortunately, it overlooked some crucial aspects of the reading process which we have identified, such as the story structure. This led to the system being overloaded by the sheer amount of knowledge contained in even a short story. Later systems tried to vary the reading depth, such as IPP (Lebowitz, 1983) and AQUA (Ram, 1991). Unfortunately, IPP failed to do any high-level reasoning, such as explanation of anomalies. AQUA added the explanation and reasoning supertask, as well as some of the memory supertask, but it ignored the story structure aspects which could have been a valuable aid.

There also exists a long history of research on reading from the teaching reading discipline. Much of this research blurs the line between task and knowledge, but the theories can still be analyzed in our framework. Graesser (1981) described six basic knowledge sources involved with textual comprehension: linguistic, rhetorical, causal, intentional, spatial, and roles, personalities, and objects. This theory is highly descriptive of the knowledge which reading needs, but the lack of a process model makes it impossible to implement. A model suggested by Clymer (1968) broke reading into decoding, grasping the author's meaning, testing and recombining the author's messages, and application/extension of the read material. This process-oriented model contains elements of the sentence processing supertask (decoding) and the story structure, scenario, and explanation supertasks (the remaining areas). Unfortunately, none of Clymer's areas were well-specified and the lack of control and explicit memory operations is a severe limitation. These approaches exist more as frameworks for exploration than as cognitive theories.

This shortcoming is certainly not the case with the last two models. Van Dijk and Kintsch (1983) propose a unified process which is responsible for the characteristics of reading. Text is transformed into *propositions* (units of information) which are combined by the reader into higher level understanding structures. The model has been extremely successful in modeling psychological data regarding the reading process, particularly research dealing with recall of read material. Despite these accomplishments, the theory fails to consider two aspects of reading which are important (for a recent discussion of these issues, see Gerrig, 1993). First, creative reading is not handled. Thus, while the theory may be valid for explaining structured reading tasks, it is unable to handle pleasure reading. Second, the theory does not place enough emphasis on the role of the author, and is forced to make reading more in-depth than it needs to be. Finally, Carpenter and Just (1988) concentrate on the working memory constraints of the reader and how these influence reading and recall issues. They, too, have had a great deal of success modeling human performance within their READER framework. The approach, however, also ignores issues of creative reading and author intent. The primary focus of their work has always been on memory's influence on reading; in that regard, their work has had tremendous success and impact on the field. Unfortunately, it is insufficient for modeling the type of reading in which we are most interested.

Conclusions

Although our theory has proven sufficient for describing the comprehension of a real-world story and many of the underlying points embodied in the theory have been supported by existing evidence from psychology and education, there are still important issues to explore. For example, in-depth evaluation of the understanding produced by the model needs to be performed. Also, the system needs to be extended with the addition of new stories for ISAAC to read; we are currently working on the addition of *Zoo* by Edward Hoch (1978). While similar to *Men Are Different*, it contains interesting variations which will help us to gauge the range of our theory's coverage and scope.

By making extensive use of the knowledge which exists within a story and by relying on a close interaction between the various reading tasks, our theory is capable of modeling the reading process to a degree not before possible. Furthermore, the theory explains pleasure reading in addition to more structured forms of reading, an area which many theories have ignored. We also provide a framework in which to analyze previous systems. Most importantly, the theory incorporates a general process of creative understanding as an integral part of reading. The power of the act comes from a willingness to not be bound by current world knowledge, to take a cognitive risk and attempt to understand something in a way it has never been understood before.

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