Understanding Causality in Science Discourse for Middle and High School Students. Summary Task as a Strategy for Improving Comprehension

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Abstract Reading comprehension involves a reader developing a mental representation of a text through the establishment of causal relations based on the ideas and events in the text. This is especially relevant to scientific text comprehension. Causal relations are fundamental to the process of comprehension as they provide a framework or scaffolding to order information in a logical way that is consistent with the argument. The most common method of assessing comprehension is based on the reader answering a series of multiple choice questions. It is unusual for comprehension measures to use an open task such as a summary. However, summaries require the reader to use writing skills as well as those of comprehension, thus revealing wide individual differences among students. This gives rise to two questions: (a) up to what point is a summary a reflection of the causal structure of a text, and (b) what—if any—is the influence of the causal relations on the comprehension of more competent and less competent readers? In this chapter we analyze the causal structure of scientific texts, as opposed to that of narratives, and explore how high school students process and comprehend these causal relations. We also examine how students' comprehension of causal relations can be evaluated by multiple choice tasks or open tasks such as summaries. Finally, we discuss some educational implications for improving comprehension in science.

Keywords Causality • Summarizing • Science discourse

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1 Science Textbooks, Strategies, and Cognitive Processes

It is a common fact that students, especially those in middle and high school, find many science texts very difficult to comprehend. Science texts frequently contain conceptualizations of ideas, explicitly specified rhetorical organization, jargon, context-bound terminology, and technical uses of terms. Furthermore, science writers frequently use abstract concepts and mathematical language (with symbols and formulas) that are difficult to ground in everyday experience and often require extreme precision. Hence, understanding what the text is about demands considerable effort. A direct consequence of these difficulties is comprehension problems, especially in those readers with poor scientific knowledge. In fact, all of these difficulties are exacerbated by the fact that most students have minimal background knowledge of science and, therefore, need to build an understanding nearly from scratch (Otero, 2002; Chambliss, 2002). An alternative scenario is that the knowledge students do possess is incorrect in some way, and it is this incorrect or mistaken knowledge that interferes with the scientific concepts and principles presented in textbooks (Graesser & McMahen, 1993; Otero & Kintsch, 1992). A consequence of all this is that students frequently develop negative epistemic attitudes toward science texts and think of them as containing incomprehensible information (Chinn & Brewer, 1993; Harp & Mayer, 1998; Otero & Campanario, 1990). These attitudes negatively influence their text processing strategies that, in turn, further limit their understanding and result in a continuing downward spiral of low motivation and even truancy (Mayer, 1999; Otero, 2009). All of these factors explain why reading science textbooks is hard and why it has become difficult to entice students to pursue a higher education in science disciplines.

2 Reading Science Texts and Writing a Summary: Some Data

Reading, regardless of whether it is understood to be a process or a skill, is generally recognized as being extraordinarily complex. It requires drawing on multiple operations whose coordinated activity enables the reader to extract, interpret, judge, and understand what has been read (Chiapetta, Sethna, & Fillman, 1991; Lemke, 1990). Far from being merely a passive and receptive subject limited to decoding, the reader takes an active role, applying knowledge and schemata as well as skills and experience to the search for meaning. It is the reader who generates what is understood, although this is based on the text.

The text itself, or rather the writer of the text, leaves clues about what is important and how the text is structured and organized. The author also illustrates particular points with good examples. All of these aspects facilitate the extraction of meaning and help the reader make sense of what he or she is reading. Thus reading involves an interaction between the reader's knowledge and the strategies he or she applies with the information in the text. Analyzing what a text means, synthesizing, answering general or specific questions, relating one section of text to another, predicting possible outcomes, judging, evaluating, detecting and repairing inconsistencies, and completing ideas where information is lacking are all just some of the multiple operations involved in this interaction between the text and the reader that result in comprehension. Reading is of such importance that many developed and developing nations are dedicating considerable amounts of time and energy into researching reading and how it can be assessed.

One fairly recent initiative is the Program for International Student Assessment (PISA), which has been in operation since the year 2000 in all the countries of the Organization for Economic Cooperation and Development (OECD, 2010). Its aim is to establish common criteria for evaluating the performance of 15-year-olds in three areas: science, math, and reading. Thirty-two countries participated in the first year, and by 2009 this number had nearly doubled to sixty-five. With respect to reading, students are required to carryout a number of different tasks such as reading for global comprehension, reading for specific information, and interpreting or reflecting on the content or structure of a text. Not only school textbooks are used, but also personal letters, fiction, biographies, web pages, and documents in the public domain (e.g., official reports, news items). This variety of texts is included in order to monitor students' reading of different kinds of materials or for different purposes.

The PISA is a standardized test that is administered in many countries, and consistently the performance of students from the U.S. or Spain (relative to the ranking of other Western nations) is below the average. Only 4 % of Spanish and U.S. teenage readers achieve the highest scores while the average for the rest of Europe is 10 %. And the situation for math and science performance is broadly similar. Thus, for the last 10 years, we have known that: (a) 15-year-old students from Spain or the U.S. do not read much and that, when they do, they are not efficient readers; (b) this negative situation has remained constant for the past 10 years; and (c) the low marks obtained in reading correlate with a comparably negative picture in math and science.

An equally interesting question is how students perform in applying their knowledge and reading strategies to a written task, such as a summary, over the course of their school lives. To address this, we carried out a large-scale study that assessed how well students at different stages of education completed a summary task (León, Olmos, Escudero, Cañas, & Salmerón, 2006). A total of 786 students took part in this study, all from schools and a university in the Madrid area. The ages included were 12 years (sixth grade), 14 years (middle school), 16 years (high school), and >21 years (third year of university). The participants were asked to read an extract of no more than 500 words taken from an encyclopedia (a general knowledge text) and, afterwards, write a summary. Evaluation was based on two criteria. The first took into account the content, paying special attention to those features showing that the original text had been simply paraphrased or synthesized in a more or less superficial way. In other words, what was assessed was the surface structure and the textbase—two mental representation levels. Thus, a summary consisting of paraphrases of the original source text or which, perhaps, included an idea expressed literally (i.e., as in the original) would be included in this type of analysis. The second method of evaluation paid more attention to coherence; that is, to the way ideas were presented, the causal connections between them, any development of the argument, the degree of synthesis, and any evidence of background knowledge used by the reader.

One of the most interesting things shown by this research was the relationship between the students' age or grade level and the kind of summary made, with differences between content and coherence being much greater at the earlier stages of education. We would expect that a child of 10 would have much fewer resources upon which to draw than a university student. Noteworthy among the results was a lack of fundamental differences between the summaries written by the 12-, 14-, and 16-year-old students. Significant improvement in summary writing was only shown by the university students. One reason for this lack of improvement in summary writing between the ages of 12 and 16 could be that students in this age range maintained the explicit ideas and the original wording of the text rather than elaborating richer and more synthesized summaries. This tendency disappeared among the university students. This could also be seen when we analyzed for type of summary (i.e., content-based or coherence-based). Students of school age tended to write summaries that closely followed the surface structure and the textbase rather than focusing on coherence. Put another way, although Spanish school-age students may have tried at some limited degree of synthesis in their written summaries, they tended to follow the structure of the source text and repeated its contents.

Together, these results seem to show that the deficiencies in summary writing extend throughout the educational system, affecting the primary levels as much as the secondary levels. One cannot help feeling that our educational system fails to invest sufficient time and resources in developing reading comprehension, metacognitive awareness, or the skills needed to write good summaries. Even worse, our educational system seems to encourage a kind of *theoretical teaching* where excellence is measured (whether by an exam, a summary, or any other kind of answer) by the students' ability to merely reproduce, in more or less paraphrased form, what a text, teacher, or other source says. Perhaps we encourage the basic levels of reading, but not the most important; the basic levels of writing, but not the most reflective.

3 The Influence of Text Characteristics and Causal Relations on Reading Comprehension

Text characteristics and text genre can influence reading comprehension. The literature frequently distinguishes between narrative and expository (e.g., science) texts (Adam & Revaz, 1996; Brewer, 1980; Harris, Rogers, & Qualls, 1998; León, Escudero, & van den Broek, 2003). Narrative texts make particular connections between facts and usually reflect reasons, the actions of a protagonist, and the problems of daily life or fiction. On the other hand, the primary purpose for reading expository texts, such as science or history, is often to search for true, universal conditions. The expository mode frequently features the conceptualization of ideas or ways to build knowledge, explicitly specified rhetorical organization, context-bound terminology, and technical uses of terms (Kucan & Beck, 1996).

Another important difference between narrative and expository texts is based on the degree of generalization and the number of observations that are needed to construct a causal explanation. Causal relation, as a basic organizational principle, is also an explanatory principle, telling us what, how, why, and when the causality occurs. Readers understand an event when they are capable of relating it to other events in a text. One of the most important links is causality. It is not surprising that those who first conducted research on comprehension suggested that causal relationships play an essential role in narrative understanding (Bartlett, 1932; Dewey, 1938; Piaget, 1927). Researchers of narrative comprehension in the 1970s shared the assumption that causal representations were central in the comprehension and memory of narratives (Mandler & Johnson, 1977; Rumelhart, 1975; Schank & Abelson, 1977; Stein & Glenn, 1979; Thorndyke, 1977). There is plenty of evidence that both the strength and the number of causal connections determine the probability of comprehension and recall of the information read as well as the level of importance assigned by the reader to the text information (Trabasso & Sperry, 1985; van den Broek, 1988). As a consequence, causal models have been prevalent in psychological studies of narrative comprehension (Graesser, Swamer, Baggett, & Sell, 1996; Langston & Trabasso, 1999; Trabasso, Secco, & van den Broek, 1984; van den Broek, 1989; van den Broek, Young, Tzeng, & Linderholm, 1999).

Some researchers have shown that establishing causality during reading can be the most important process involved in comprehension (León et al., 2003; León, Solari, Olmos, & Escudero, 2011; Sundermeier, van den Broek, & Zwaan, 2005). Through five experiments, Sundermeier et al. (2005) demonstrated how causal and spatial information is constantly coded and updated during reading, especially when this is necessary to establish causal coherence. Some authors consider causal inferences to play a fundamental role in comprehension and have given them greater attention (McKoon & Ratcliff, 1986; van den Broek, 1990), and it is causal criteria which mainly guide inferential processing (Díaz & de Vega, 2003; van den Broek, 1990). This idea arises from the fact that the reader constructs a text-based and a situational model that are very sensitive to the availability of causal information (Sundermeier et al., 2005). Given that this procedure is necessary to construct a coherent global representation, the search for causal relations becomes the key to comprehension as a process and as a result (León, 2004).

Usually, in the comprehension of daily events or simple narratives, chronological order is a main criterion to organize causality. As noted, we learn causality by discovering the co-occurrence between causes and effects in the real world, in that causes precede effects. However, in a scientific context, it is not always possible to organize causality chronologically. Understanding science often amounts to grasping the meaning of some scientific generalization and using it to explain a specific situation in which the generalization figures (Newton, 1995). In addition, many scientific explanations reverse the order of causality. They start with the presentation of the problem and then try to answer the question of *why* the problem has occurred. The reasons why scientific explanations appear in this way could be connected with the complex conceptual analysis needed in order to interpret reality according to scientific principles.

Scientific explanations are often causal (León & Peñalba, 2002; Ohlsson, 2002; Salmon, 1998) and elicited by posing *why* questions. That is, when we give scientific explanations, we answer *why* a particular phenomenon occurs. For instance, it is common knowledge that all the living beings, animals or plants, are fighting for their survival and, in so doing, develop strategies of adaptation to the environment. These and many other beliefs make up our commonsense causal understanding of the natural world, including human beings and their interactions with nature. The characteristics of this system and the way it operates are a matter for scientific debate. That is, we produce scientific discourse with explanations of, for example, *why* adaptation occurs, *what* it means, *how* and *when* it takes place, and *what* the consequences are.

Given that global coherence relations are primarily of a causal nature, it is important to bear in mind that this coherence arises through the reader connecting broad segments of the text and re-organizing information derived from the text within a structured representation that is integrated into a global causal structure (Escudero & León, 2007; León, 2003). Global coherence is a representation of text comprehension that includes the mental model and the causal network generated by the reader from the information in the text. Causal information, then, is fundamental to the process of comprehension as it provides a framework or scaffolding on which to order in a logical way information consistent with the argument. There is some evidence that, compared to novel or inexpert readers, expert readers organize information on more abstract levels with general strategies, laws, and principles (León & Peñalba, 2002; León & Pérez, 2001).

Some models and theories in discourse psychology have focused on the psychological mechanisms that underlie the comprehension of causal relationships in these scientific contexts. There have been investigations of the inferences that explain, elaborate, or predict events in causal chains in science (Britton & Black, 1985; Graesser & Bertus, 1998; Millis & Graesser, 1994; van den Broek, Virtue, Gaddy, Tzeng, & Sung, 2002). Sometimes it is difficult to comprehend the text because of the lack of subject matter knowledge; whereas, at other times there is a lack of text coherence. These barriers make it difficult, if not impossible, to link the text causally (McKeown, Beck, Sinatra, & Loxterman, 1992). Therefore, science texts require more intense processing than narrative texts. Comprehending science discourse requires different kinds of knowledge to form an explanation (e.g., conceptual and abstract knowledge), mathematical and logical argumentation, and procedural or strategic action.

4 The Importance of Summaries in Comprehension Processes and Reading Competence

One area of text comprehension research that has most interested psychologists and discourse researchers concerns the processes that occur during the comprehension and summarizing phases of reading. Comprehension and summarizing are very closely related. In fact, some researchers (e.g., Palincsar & Brown, 1984) have suggested that if readers are not able to summarize a passage, then they have not understood it. A generally acknowledged practice consists of using a summary to organize and emphasize the most relevant content of the text. Although the summary concept is imprecise, summaries themselves hold a significant place in scientific texts, and their effectiveness in improving comprehension and recall is generally recognized (Hartley & Trueman, 1983; Kintsch, Steinhart, Stahl, & LSA Research Group, 2000; León & Carretero, 1995; Lemarié, Lorch, Eyrolle, & Virbel, 2008; Lorch & Lorch, 1986, 1996; Lorch, Lorch, Ritchey, McGovern, & Coleman, 2001). When readers summarize a passage, they tend to form a nucleus of information, a core concept that represents a general vision of the text in a coherent way. Synthesis and coherence are two key aspects of a good summary. In order to summarize a text, a reader must read and comprehend the material, isolate the main ideas, and convey those ideas succinctly. In general, we can assume that a summary is a concise statement of the most important information in a text. A summary should describe most of the main ideas (or main topics) in the text. The ability to be concise is very important in some instances such as when submitting a scientific article or a proposal for meetings or conferences that usually require an abstract of 100 words or fewer. Because this task involves deeper processing—including writing strategies such as generalization, synthesis, and maintaining coherence (e.g., Brown, Day, & Jones, 1983; van Dijk & Kintsch, 1983)—it is more complicated than simple reading. Summarizing is especially important in educational and professional contexts (e.g., training in reading and writing strategies and assessments and in e-learning assessment, respectively).

The nearness of a causal chain can be a strong predictor of how the events of a story are rememembered (Khoo, Chan, & Niu, 2002). Causal relations, and the density of these relations, affect the reader's perception regarding the importance of these events for the story. The events with more causal connections and which occur as part of a causal chain from the beginning to the end of a story are judged by the reader to be more important and can be used in open tasks such as summaries or reports. This gives rise to the question of whether the causal structure of a text can determine how or to what degree the layers of a text can be understood, remembered, and used in different tasks. Many cause-effect relations in a text are inferred by the reader using information in working memory and long-term memory. Furthermore, some researchers have suggested that the goal of narrative comprehension is to discover the order of causal links that connect the beginning and end of the text (Khoo et al., 2002). In a recent study we assessed reading comprehension, analyzing the causal network in a narrative text and comparing this to the causal networks

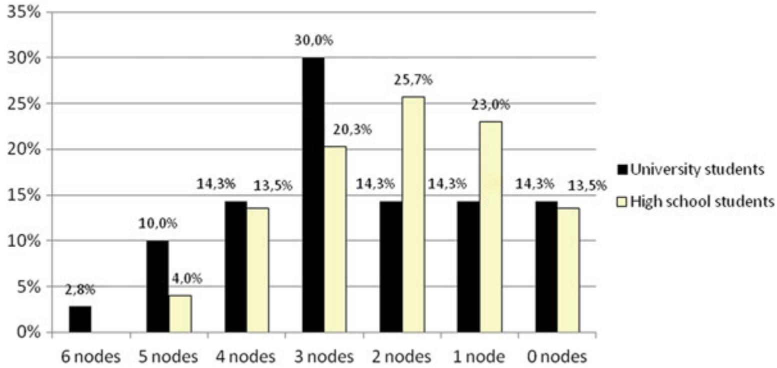

Fig. 1 Percentage of students using the key causal nodes in narrative text, by group (León et al., in press)

generated by the students in their written summaries of the original text and a multiple choice test (León, Escudero, & Olmos, in press). A total of 144 students (74 from high school [15–16 years old] and 70 undergraduate students) took part in this study. The main hypotheses behind this study were that causal density, or more specifically those nodes in a text that have a greater number of causal relationships, will have a greater effect on reading comprehension, and that the identification of the causal relationships in a text is one of the factors that distinguishes more competent from less competent readers. The results supported these hypotheses and, furthermore, enabled us to detect a predictive value between the recognition of causal nodes and types of reader (see Fig. 1).

Figure 1 shows the percentage of *key nodes* used by each group of students in their summaries. As can be seen, most of the university students based their summaries on three nodes while the high school students used between one and two. Only two university students (less than 3 % of that group) and no high school students seem to have identified all six key nodes. No high school students established six relations while three high school students used five nodes. Given these results, the correlations between each student's answers to the multiple choice comprehension questions and the number of points she or he had been awarded for the summary were compared. It was observed that the points awarded for the summary were moderately related to the representation of the textbase and to that of the mental model. As expected, this relation shows a slightly positive tendency. In other words, those students who can generate a good textbase and/or mental model tend to be good at summarizing the text.

A large number of experimental studies have also shown that writing a summary not only aids comprehension but also aids memory for the content of the source text (e.g., Anaya, 2005; Hidi & Anderson, 1986; Kintsch, 2000; Rinehart, Stahl, & Erickson, 1986). More specifically for our purposes, other studies have made clear that a summary is a good measure of comprehension (e.g., Al-Shabanah, 2005; Armbruster, Anderson, & Ostertag, 1987; Cordero-Ponce, 2000;

Jorge & Kreis, 2003; Kirkland & Saunders, 1991; León et al., 2006; Nelson & Smith, 1992; Taylor, 1983; Thomas & Bridge, 1980; Vadlapudi & Katragadda, 2010; Zipitria, Arruarte, Elorriaga, & Díaz de Llarraza, 2007). In their study, Thomas and Bridge (1980) obtained a very high correlation ($r = 0.80$) when they compared comprehension measured through a cloze test to comprehension measured through a summary. Nelson and Smith (1992) evaluated the quality of summaries in relation to the content, calculating the amount of important information included in each summary expressed as a percentage of all the main ideas in the text previously identified by expert judges. Research by Armbruster et al. (1987) and Cordero-Ponce (2000) follows similar lines. Furthermore, a number of studies conclude that comprehension ability shown by readers at an early age is a powerful predictor of comprehension in later years (Oakhill & Cain, 2007). In the final year of primary school, reading comprehension becomes especially important—above all because it establishes the basis for learning in high school. In fact, the academic progress of students who have poor reading comprehension or low motivation to read is severely limited (Guthrie et al., 2004).

Many research findings support the idea that coherence is central to discourse comprehension as well as to summarizing. Coherence is accepted as a main characteristic of a reader's mental representation of text content. Coherence relations are constructed in the reader's mind and depend on the skills and knowledge that the reader brings to the situation (Graesser, Singer, & Trabasso, 1994). A summary is considered to reflect how coherent (or incoherent) an understanding of the text the reader has. To summarize well, a reader must first perceive a text as coherent and then ensure that the ideas conveyed in the text hang together in a meaningful, organized, and synthetic manner. This analysis requires differing integrated levels of representation, including text-based models (based on topics and ideas from the text) and situational models (based on the reader's prior knowledge). As a result, summarizing is a highly effective means of constructing and integrating new knowledge. Many aspects of discourse contribute to coherence, including co-referencing, causal relations, connectives, and signals. These are highly correlated with other coherence factors such as causal relations found in the text (Trabasso et al., 1984). The potential for summarization to improve comprehension is high because it requires much more active meaning construction than choosing the best response from a set of choices or even writing short answers to isolated questions. Perhaps for this reason, as some authors suggest (e.g., Kintsch et al., 2000), summarizing may be a more authentic method for assessing what readers do and do not understand about a text than traditional comprehension tests.

5 The Representation of Scientific Text and Strategies for Summarizing

The content of scientific texts has multiple levels of representation, but the most important split is between shallow and deep knowledge. Shallow knowledge consists of explicitly mentioned ideas in a text. These can include lists of concepts, a handful of simple facts or properties of each concept, simple definitions of key terms, and major steps in a procedure (not the detailed steps). Deep knowledge consists of coherent explanations of the material that fortify the learner for generating inferences, solving problems, making decisions, integrating ideas, synthesizing new ideas, decomposing ideas into subparts, forecasting future occurrences in a system, and applying knowledge to practical situations (see Graesser, León, & Otero, 2002). Deep knowledge is essential for handling challenges and overcoming obstacles (when there is a need to understand how mechanisms work, for example), and for generating and implementing novel plans. Explanations are central to deep knowledge, whether the explanations consist of logical justifications, causal networks, or goal-plan-action hierarchies. It is well documented that the construction of coherent explanations is a robust predictor of an adult's ability to learn technical material from written texts (Chi, de Leeuw, Chiu, & LaVancher, 1994; Cote, Goldman, & Saul, 1998; León & Peñalba, 2002; Webb, Troper, & Fall, 1995). These different levels of mental representation also correspond to different ways of summarizing, each with their own appropriate strategies. These will be discussed in the next section.

5.1 Surface Code Level

This is the shallowest level, which preserves the exact wording and syntax of the explicit verbal material. Only the most recently read clauses are retained in memory and then only for a short time unless we make some effort to remember them. There are instances when this kind of mental representation is essential; for example, when we try to learn the lyrics of a song or recite poetry. In both these cases, words and syntactic organization are preserved in an identical way to the original. However, although memorizing a text allows us to recreate the superficial structure, it does not mean we have understood the text. Rather, it is a literal reproduction, a repetition that may not carry any meaning or bring us to an understanding of what is written.

The *copy-delete strategy*, proposed by Brown et al. (1983), occurs at this level and these authors found that it was relatively common among primary school students. Using this strategy, the ensuing summaries can be characterized by being shortened copies of the text. The important ideas and sentences are repeated more or less word for word and the surface structure of the text is maintained. Ideas are not combined with others, nor are they paraphrased; and if the summarizer runs out of space to write, he or she simply stops. For example, if a text to be summarized contains 20 sentences, a student using this strategy might choose those sentences that he or she thought were the most important (say, sentences 3, 5, 6, 7, 12, 13, 15, and 20). These eight sentences would then be copied literally from the text while the remaining superfluous sentences would be ignored.

5.2 Textbase Level

The textbase is an interconnected network of the explicit propositions contained in the text. These may correspond to exact phrases but will also consist of abstract representations and paraphrases as well as a number of inferences necessary to establish coherence at the local level. The textbase preserves the meaning of the source text but not necessarily in the original words or syntax.

The textbase is useful in many comprehension tasks that require reference to explicit information in a text such as searching for or identifying specific details or connecting information across different sections of the text. For understanding to occur, the reader must build a mental representation made up of the meanings associated with the ideas and sentences contained in the text. For example, consider the following short text proposed by Otero, Caldeira, and Gomes (2004, p. 55):

> The water contained in a cloud is in the form of miniscule drops that reflect the light. It is this which gives clouds their characteristic white color.

A student who is asked to write this text from memory might begin in the following way: "The water in a cloud is made up of tiny drops ....". We can see that the text has been paraphrased and does not have an exact correspondence with the original; nevertheless, the meaning has been preserved.

With respect to the summary writing strategies associated with this level of representation, better readers usually focus only on relevant information, apply rules for condensing the information, and produce more succinct and coherent texts. The following steps were outlined by Brown et al. (1983): (a) delete unnecessary information; (b) delete redundant information; (c) substitute a list of names or events with a superordinate term; (d) substitute a number of subcomponents of an action or sequence of actions with a superordinate term; (e) select a topic sentence; and (f) if there is no topic sentence provided by the text, generate one.

5.3 Mental Model or Situation Model

At the deepest level, there is the mental model (or situation model) of what the text is about. This level of representation is more similar to our own experience of the situation or event described in the text than to the grammatical or structural characteristics of the text. To give an everyday example, the situation model of an internal combustion engine might include the electronic or mechanical components of the system, the spatial arrangement of these components, the causal chain of events when the system is working, the mechanisms that explain each causal step, the functions of the components, and the plans of agents who manipulate the system for various purposes.

The mental model is more complex as it requires the reader to integrate propositions in the text with his or her own background knowledge and to generate inferences. Thus, evaluation of this level of comprehension is fundamental to our concerns because in order to achieve a good understanding of the text, the reader must supply a great deal of implicit information. This is achieved through making inferences, deductions, and abstractions; associating ideas; predicting; and so on. All of that may influence further processes after comprehension such as interpreting or judging. By evaluating the mental model, we can see whether a reader's comprehension is subject only to the explicit information contained in a text or, on the other hand, whether it is more reflective, efficient, and complete. For the purposes of evaluating reading, this level complements the previous levels as it can show us what problems might result from an inadequate understanding or even the causes of a poor understanding. We could say that it allows a measure of depth of comprehension as well as a measure of efficient reading competence.

To continue with our earlier example of the clouds, suppose that after reading the text, another hypothetical reader asks himself or herself the following: "If clouds are white because the sunlight is reflected by tiny drops (technically speaking, *droplets*), why do they sometimes look gray?" This raises the question of whether this reader's understanding of the text is identical to that of the reader who simply stores the meanings of the words in memory. The answer would seem to be: no. In the second case, the reader actively tries to relate the information in the text to his or her previous background knowledge. In fact, the reader finds that the information in the text (clouds are white) is incompatible with what he or she knows (some clouds are gray). In other words, this reader has generated a richer mental representation than the first reader—one that contains information from the text as well as what he or she already knows. The mental model, then, corresponds to a cognitive representation of actions, events, persons, or whatever the situation described in the text is, and to that is added information from the reader's own knowledge and experience.

As with the textbase, the summarizing strategies associated with the mental model include focusing on what is relevant and condensing the information to a more succinct yet coherent form by applying the following rules: (a) delete unnecessary information; (b) delete redundant information; (c) substitute a list of names or events with a superordinate term, or substitute a technical term whether this is in the text or not (*droplets* in our example above); (d) substitute a number of subcomponents of an action or sequence of actions with a superordinate term; (e) select a topic sentence; and (f) if there is no topic sentence provided by the text, generate one (based on background knowledge). Furthermore, at this level, students may review their summaries to check whether they contain sufficient information (Hare & Borchardt, 1984) as well as review them for coherence (León, 2004).

In conclusion, a summary is considered to be a highly complex task, requiring as it does metacognitive abilities not only to identify and select relevant information, but also to organize, interpret and, ultimately, assimilate information in a critical and personal fashion. In all of these operations the reader must endow what he or she reads with meaning by relating it to what he or she already knows. Put another way, the reader endows his or her own representation of the text with meaning by, on the one hand, reducing and synthesizing the information contained there and, on the other, extending or deepening this further by adding his or her own knowledge and experience. The evaluation of summaries can be more effective if we take into account the use the reader or summarizer makes of the three levels of representation.

6 Using the Mental Representation as a Strategy of Improve a Summary

Some authors, such as Kirkland and Saunders (1991), suggested that summaries should be evaluated on the basis of four criteria that they claimed were appropriate for expository texts. The four criteria were: (a) the summary provides a general overview of the text and emphasizes the relations existing between the main ideas, (b) the information given is clarified by secondary ideas, (c) the vicarious character of the summary with respect to the source text is clear or even made explicit, and (d) the summarizer uses his or her own words. In their summary analysis model that draws on the work of several writers, Jorge and Kreis (2003) used five parameters to measure the quality of summaries: cohesion and coherence, inclusion of the main ideas contained in the source text, conciseness, information about the source text, and absence of personal opinion. A similar study was carried out by Zipitria et al. (2007) who developed a system based on observing and analyzing the processes used by expert evaluators of summaries. Zipitria and his colleagues identified variables (e.g., coherence and cohesion, appropriate and correct language, appropriate, correct and relevant content) and examined the overall contribution each of these made to the quality of the summary. The evaluators gave a global mark to the summary as well as marking each variable on a scale of 0–10. This study also reported a statistical analysis which showed a certain independence of the variables. A generalized conclusion of all these studies is that a summary task encourages deep understanding of the text because it requires active construction of the meaning as opposed to merely choosing one response from several alternatives or answering isolated questions. As such, writing summaries can be a valuable complementary instrument to traditional methods (i.e., multiple choice) of evaluating students' comprehension of science text.

We proposed that summaries should be evaluated on the basis of three criteria that were found to be appropriate for expository as well as narrative texts (León et al., in press). The three criteria were *content*, *coherence,* and *cohesion or written expression. Content* concerns the extent to which the summary reflects the essential content of the text. Evaluation is based principally on the textbase; that is, on whether the most relevant ideas have been included. *Coherence* is the main characteristic of a reader's mental representation of text content. Coherence relations are constructed in the reader's mind and depend on the skills and knowledge that the reader brings to the situation. This analysis requires differing integrated levels of representation, including text-based models (based on topics and ideas from the text) and situational models (based on the reader's prior knowledge). As a result, summarizing is a highly effective means of constructing and integrating new knowledge as well as connecting causal relations between the relevant ideas, including reasons and consequences. These aspects should be clear and explicit in a good summary. Along with other details supplied by the reader, the aspects also give greater coherence to the summary. Finally, *cohesion or written expression* refers to the style and form of the summary. The characteristics that are evaluated positively are the use of paraphrasing, correct synthesis, and whether the summary is personalized; that is, whether the writer has used his or her own words. Characteristics that are evaluated negatively or even penalized are the inclusion of unnecessary or irrelevant information, the repetition of ideas, the use of the copy-paste strategy, and whether the summary is too long (and, hence, probably contains superfluous details).

The three criteria can be observed in a summary of the following science text sample:

Strangling Trees

A strange plant grows in some tropical forests. These are the *strangling trees*, one of the most curious examples of adaptation to the environment. When young, these trees are climbers; growing around the trunk or branches of other forest trees. As it climbs up its host, however, the strangling tree envelopes it in a mass of dense roots, suffocates it until it dies, and then lives as an independent tree.

The reason for this behavior is that, in the tropical forests, there is great competition for light and sun. A young plant just poking out of the dark forest floor, and not especially adapted to the conditions there, has little chance of survival unless it can reach the light it needs at the tops of the trees. The stranglers solve this problem by using other trees to reach their own "place in the sun" among the dense tangle of branches which makes up a tropical forest.

Some of the most common stranglers are certain fig trees from Brazil. The seeds of these strangling figs usually germinate in a high branch of an existing tree, probably carried there by birds or fruit-eating bats. The resulting plant produces two types of roots: one kind climbs up the trunk and branches of the host while the others reach down to the forest floor, either following the trunk or simply dangling in the air. The stem grows upwards toward the light. This young plant is an epiphyte; that is, a plant which lives on another but does not take anything from it.

Once the downward growing roots reach the forest floor, the strangler's growth accelerates. Its roots thicken rapidly and it can grow many leaves and branches. Viewed from the ground it is almost impossible to distinguish which parts of the tree belong to the strangler and which to the host. It is now when new roots are formed and begin to spread themselves over the host's trunk. After some time, these roots form a dense mesh around the host tree that gradually gets tighter and tighter.

This is when the strangler kills its host not only preventing its trunk from getting bigger, but also squeezing it, crushing it, so that the sap can no longer circulate and nourishment can no longer reach its branches or leaves.

While it is choking its host, the strangler's roots continue growing, getting more and more robust until they completely cover or nearly cover the trunk. When the host tree dies, the strangler becomes an independent tree with its own leafy canopy. Some stranglers are the biggest trees in the tropical forest.

Strangler trees are not only common in Brazil. They can be found in the humid rain forests of Australia, New Zealand and several other countries (León, Escudero, & Olmos, 2012, p. 8, reprinted with permission).

A summary of this type of text could be as follows:

In humid rain forests (Brazil, New Zealand, Australia) the high density of vegetation means that very little light reaches the forest floor, so there is great competition for light and sun. In order to survive (adaptation to the environment, survival strategy) some trees (e.g., Brazilian fig tree; an epiphyte) adopt the curious strategy of climbing up a host tree, eventually smothering it in a mass of dense roots which, in the end, squeeze the host tree so tightly that the sap can no longer circulate. The host tree dies and the strangler tree occupies its place as an independent tree.

With regards to the **content** of the summary, the information included should explicitly mention the strangler tree and the host tree, as well as the strangling process described in the first paragraph of the text. Also important is the fact that the strangling tree and the host co-exist at first, but eventually the strangler chokes the host and ends up living as an independent tree. Analogies (e.g., *it is or acts like a vine*; *it is a kind of climbing plant but much bigger*; *it is a creeper*), are useful, as is describing the two possible routes: *one kind climbs up the trunk ... while the others reach down to the forest floor*. Other central ideas that should be mentioned are the reason for the strangler tree's behavior (the why), in particular the fight for survival (adaptation in general) or the competition for sunlight (adaptation to a specific condition).

Attending to **coherence**, there is a more or less clear causal thread running through our sample science text (general idea: *Strangler trees have a curious way of fighting for survival and in trying to reach the sunlight in dense tropical forests*) and a survival strategy (*Although at first they co-exist with a host tree, little by little they surround it from top to bottom with their own roots so that, in the end, they asphyxiate it and take its place as independent trees*). The order of the ideas follows the logical sequence (i.e., FIGHT FOR SURVIVAL – STRATEGY OF ADAPTATION). Although if it were the reverse (i.e., STRATEGY – FIGHT), it might also be acceptable, providing the essential ideas are included.

Finally, with respect to **written cohesion**, the ideas should be expressed clearly and flow easily from one sentence to another. This summary uses paraphrasing and correct synthesis, and the summary is personalized—the writer has used his or her own words.

This system of assessment permits us to compare other examples of poor or incomplete summaries of adolescents:

– *This text talks about how strangling trees kill people, these trees are found mainly in Brazil, New Zealand and other several countries, talks also about the roots and seeds of these trees.* (Middle School, 14 years old)

– *This talks about one of the strangest adaptations to the environment. In the beginning these plants grow like a creeper around the trunk and branches of an ordinary tree in the forest.* (High School, 16 years old)

Examples of acceptable (or nearly acceptable) summaries written by adolescents include the following:

– *This talks about trees which strangle other trees because they fight for the light. Birds take the seeds up to the highest branches of other trees. The roots grow downwards, surrounding the tree and strangling it.* (Middle School, 14 years old)
– *The text talks about a tree which slowly kills other trees in its search for light and in this way can survive. Little by little these trees surround their prey and then squeeze and squeeze until the sap can't circulate. The plant is called "Brazilian fig tree" but they also exist in New Zealand, Australia and Brazil.* (High School, 16 years old)
– *Strangling trees are plants which have adapted to the environment, they strangle another tree until it dies and then live as an independent tree. They do this because of the competition for light and sun.* (High School, 16 years old)

We can also apply the three criteria to identify adolescents' good or excellent summaries:

– *In some tropical forests in Brazil, Australia, New Zealand, etc., a strange type of tree grows, the stranglers. These trees grow like creepers around another typical forest tree, climbing up the trunk in search of sunlight. Once they have reached the top and their roots are in the ground, they begin to squeeze and crush the trunk of the trees they are living on to later occupy their places in the forest.* (Middle School, 14 years old)
– *For the vegetation in the forest, survival is a war to get light. The strangling tree is an example. It grows in several countries in different parts of the planet. Stranglers have adapted to the environment in order to survive. Like every plant they need light and their way to get it is by germinating their seeds, which most probably have been digested by fauna (birds) in the branches of a tree where they grow, surrounding the host tree until they kill it (through asphyxia) when they occupy its place.* (High School, 16 years old)

Academic texts like *Strangling Trees* as well as others, including narrative texts, have been analyzed recently in different studies using summary task and multiple choice tests (León et al., in press; León, Olmos, Perry, Jorge-Botana, & Escudero, 2013). These studies were designed around three main objectives. The first objective was to test whether a summary task would predict the reading comprehension ability of students at different education levels: middle school, high school, and university. The second objective was to determine whether symmetry/asymmetry of the summary task was a predictor of reading comprehension ability. The third objective was to examine whether a summary task would predict reading comprehension ability when using source texts of differing degrees of complexity.

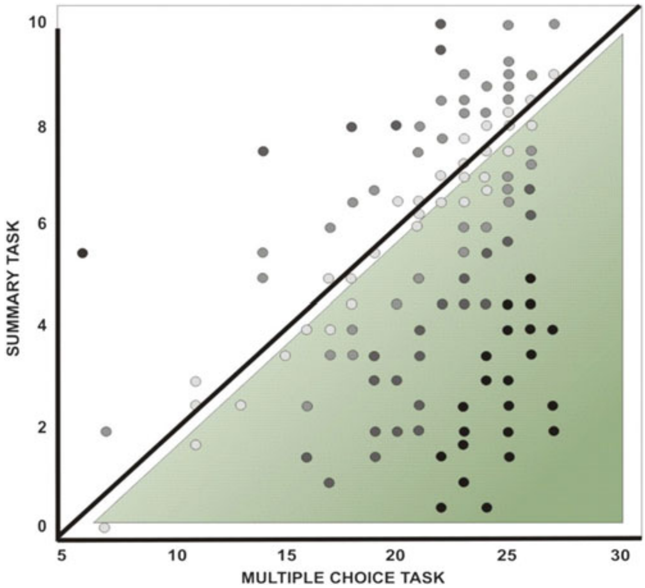

Fig. 2 Dispersion diagram showing the effect of the one-way asymmetry between the scores for the multiple choice test and the summary task for the *Candies* text for all groups (León et al., in press)

The results obtained suggest that summary writing can indeed be used as a predictor of reading comprehension, at least when this is measured using a multiple choice test. Furthermore, an examination of the data for both the expository and narrative text types used show that between the multiple choice reading test and the summary task there is a one-way asymmetrical effect, while in the reverse direction (from the summary to the multiple choice test) the effect is symmetrical. This is depicted in Fig. 2.

In practical terms, this indicates that although the result of a multiple choice reading test would not guarantee or predict the quality of a given student's summary, the quality of the summary could be used to predict the same student's performance on the reading test. We may conclude that a summary may be used to predict reading comprehension as measured by a multiple choice test. This has occurred with two distinct texts with different levels of difficulty and with participants at different stages of education (middle school, high school, and undergraduate students). The predictive nature of a written summary can be interpreted in the sense that a student who obtains a high mark for his or her summary will probably also obtain a high mark in more traditionally evaluated reading comprehension. Similarly, we would expect a student who achieved a low mark in the summary to not do very well in a multiple choice reading test. Therefore, summary writing can be said to have a predictive value for reading comprehension and, in turn, of reading competence.

One possible interpretation of this data is that a summary task is much more complex than a multiple choice test; apart from engaging the cognitive processes involved in reading comprehension, it also requires control over the processes used in written production. As discussed earlier, producing a written summary requires the writer to abstract the essential ideas, to establish coherent relations among them, to distinguish between relevant and irrelevant details, and to construct a logical internal mental representation of all these that is true to the semantic relations in the text. Moreover, it involves writing strategies and confronting an already existing text. These skills, in turn, imply the writer is actively evaluating the relative importance of text information. In short, writing a successful summary requires planning and control over one's own comprehension.

7 Conclusions

In this chapter we support the idea that the summary writing is a valuable learning activity because it helps readers build a coherent mental representation of the text, which is the foundation for adequate and consistent learning. This learning activity is special more relevant when reading and understanding science texts because it involves more time and effort than narratives to construct a mental model of an event and a causal explanation. It also takes more time to process the features of academic discourse: technicality, abstraction, complexity, and inclusion of expert knowledge.

Several characteristics of the summary writing may be important in this regard. First, a summary not only requires production of a written text, but also presupposes the skills and processes that are involved in comprehension. Currently, it is assumed that a summary writing task demands considerable effort on the part of the reader as he or she advances through the source text in order to differentiate between relevant and irrelevant ideas and concepts, decide on the ideas and details upon which a coherent internal mental representation of the semantic relations in the text will be built, and establish coherent relations between the ideas. Thus, a summary task encourages the reader to carryout a systematic exploration of stored information, encourages text structure strategies, and strengthens the connections between old and new information. Second, summary tasks require a degree of planning and control over one's comprehension. They stimulate the use of metacognitive skills and favor the development of self-regulation strategies, all of which have a positive impact on knowledge building and learning from written texts. Third, underlying the use of all these strategies is the basic idea that to summarize a text one must first understand it, and the better the understanding, the better the summary will be. Perhaps it is for this reason that asking readers to write a summary is considered by some researchers as one of the best methods of evaluating comprehension (Idris, Baba, & Abdullah, 2008).

The predictive nature of a written summary on text comprehension can be interpreted in the sense that a student who obtains a high mark for his or her summary will probably also obtains a high mark in reading comprehension. Similarly, we would expect a student who achieved a low mark in the summary to not do very well in a multiple choice reading test. Therefore, summary writing can be said to have a predictive value for reading comprehension and, in turn, of reading competence (León et al., in press). The three criteria (i.e., content, coherence, and cohesion) are relevant to evaluating summary tasks adequately.

Summary writing tasks can help students learn higher level writing and comprehension strategies. Writing summaries is not only relevant to the study of comprehension, but also has other educational applications. For example, Hadwin, Kirby, and Woodhouse (1999) studied variables such as summary writing, working memory, verbal ability and background knowledge as predictors of both good summary writing and of memory for content. They found that the quality of written summaries was the best predictor of academic performance and of individual differences between students.

Finally, we highlight that summary writing is a valuable learning activity requiring more research. The education system in general needs to invest more time on developing the strategies required for writing good summaries. We might even say that the secondary educational system fosters a type of theoretical teaching where *excellence* means the capacity to reproduce a text, or whatever the original form was, regardless of whether this be on an exam, in writing a summary, or providing any other kind of answer. This would require a drastic change in current practice and present a challenge that must be met by educators in the near future.

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