Psicología Educativa (2019) 25(2) 159-167

Psicología Educativa

https://journals.copmadrid.org/psed

# Contributions of Causality Processing Models to the Study of Discourse Comprehension and the Facilitation of Student Learning

Jazmín Cevasco[a] and Paul van den Broek[b]

[a]National Scientific and Technical Research Council, Argentina; [b]University of Leiden, The Netherlands

ARTICLE INFO

*Article history:*
Received 12 January 2019
Accepted 24 April 2019

*Keywords:*
Discourse comprehension
Causal connections
Coherence
Inferences
Learning

ABSTRACT

Discourse comprehension involves the establishment of semantic or meaningful causal connections. The aim of this paper is to review four models that have contributed to the study of the establishment of these connections: the Causal Chain Model, the Causal Network Model, the Causal Inference Maker, and the Landscape Model. These models contribute to the facilitation of student learning, given that they provide useful tools for improvement of texts structure in order to promote the establishment of meaningful connections and the revision of students' prior incorrect ideas, and for the design of interventions that promote the generation of inferences and the monitoring of comprehension. The presentation of their key ideas, of empirical support for their psychological validity, and of applications to education will allow us to highlight the contributions that these models make to our understanding of the importance of the processing of causality for discourse comprehension and the facilitation of student learning.

## La contribución de los modelos de procesamiento de la causalidad al estudio de la comprensión del discurso y la facilitación del aprendizaje del alumno

*Palabras clave:*
Comprensión del discurso
Conexiones causales
Coherencia
Inferencias
Aprendizaje

RESUMEN

La comprensión del discurso implica establecer conexiones causales semánticas o significativas. El objetivo de este artículo es revisar cuatro modelos que han contribuido al estudio del establecimiento de estas conexiones: el modelo de cadena causal, el modelo de red causal, el modelo generador de inferencias causales y el modelo de paisaje. Estos modelos contribuyen a facilitar el aprendizaje de los estudiantes, dado que proporcionan herramientas útiles para mejorar la estructura de los textos con el fin de promover el establecimiento de conexiones significativas y la revisión de las ideas previas incorrectas de los estudiantes, y para el diseño de intervenciones que promuevan la generación de inferencias y el monitoreo de la comprensión. La presentación de sus ideas clave, de la evidencia empírica que apoya su validez psicológica y de las aplicaciones de sus herramientas a la educación permitirá resaltar las principales nociones que estos modelos hacen a nuestro entendimiento de la importancia del procesamiento de la causalidad para la comprensión del discurso y la facilitación del aprendizaje de los estudiantes.

The establishment of meaningful connections among statements is key to the comprehension of expository and narrative texts (Karlsson et al., 2018; van den Broek, 2010; van den Broek & Helder, 2017; Zwaan & Rapp, 2006). In particular, causal connections are central to the construction of a coherent representation of discourse. By identifying causes and consequences among spoken and written ideas, students construct a coherent representation of the topics that the instructor presents during the class (Kendeou, van den Broek, Helder, & Karlsson, 2014; McMaster, Espin, & van den Broek, 2014; Sparks & Rapp, 2010). As a consequence, it is important to explore the contributions that models that examine the establishment of these connections make to the facilitation of student learning. The aim of this review is to present four models that have focused on this topic: the Causal Chain Model, the Causal Network Model, the Causal Inference Maker, and the Landscape Model. These models examine how students establish meaningful causal connections among statements, what role the establishment of a network of these connections plays in the construction of a coherent representation of discourse in memory, what cognitive activities are involved in the generation of causal inferences during the processing of texts, and how the processing of causal connections and the construction of a coherent representation of the text in memory interplay. These models were developed primarily in the context of comprehension of narratives, but their tools have also been applied to the study of expository texts. Prior research also has tended to focus on the comprehension written texts but recent investigations are starting

Cite this article as: Cevasco, J. & van den Broek, P. (2019). Contributions of causality processing models to the study of discourse comprehension and the facilitation of student learning. *Psicología Educativa, 25,* 159-167. https://doi.org/10.5093/psed2019a8

Correspondence: jazmincevasco@psi.uba.ar (J. Cevasco).

to apply them to examine the comprehension of spoken discourse. Considered together, the tools provided by the models contribute to the development of procedures for improving the structure of texts to facilitate the establishment of meaningful connections and the revision of students' prior incorrect ideas, and to the design of interventions that promote students' generation of inferences and comprehension monitoring. The presentation of their central notions, the results of studies that provide evidence that supports them, and the applications of their tools to education will allow us to highlight the contributions that they have made to our comprehension of the importance of the processing of causality in the comprehension of discourse and the facilitation of student learning[1].

With this aim, we first present the key ideas of each model. This allows us to examine their central notions for analyzing comprehension, and how they overcome the limitations of prior models. Next, we will present studies that have tested their proposals, and applications of their conclusions to education. This will allow us to highlight the empirical evidence that supports their psychological validity, and the contributions that they make to the promotion of student learning.

## Causal Chain Model

The Causal Chain Model (Black & Bower, 1980; Omanson, 1982; Schank & Abelson, 1977) proposed that the causal structure of a narrative can be described as a chain of events, such as attempts to obtain goals, actions and changes of states as a consequence of these actions, that leads from the beginning to the end of the text. This model was inspired by Story Grammars (e.g., Mandler & Johnson, 1977; Stein & Glenn, 1979), which capture how different types of events tend to be ordered in narratives.

This chain begins with statements that introduce the protagonists and their goals. Once they are established, these goals lead to *attempts* to attain them, which lead to *results.* Events that have at least one cause and one consequence are part of the causal chain. Events that do not have at least one cause and one consequence are *dead ends*. These tend to involve actions with no consequences. The chain ends when the protagonist's goal is attained or fails. Table 1 presents a sample story. Figure 1 presents its causal chain representation:

**Table 1.** Sample Story

| |
|---|
| 1. One day, Pedro was navigating the internet. |
| 2. He saw an ad for an iphone, |
| 3. and he liked the model. |
| 4. He decided that he wanted to get it. |
| 5. He contacted the website to ask for the price. |
| 6. He realized that he did not have enough money. |
| 7. He decided to get a delivery job. |
| 8. For a couple of months he woke up early, |
| 9. in order to be free in the afternoons, |
| 10. to do his job. |
| 11. Pretty soon he earned the money that he needed. |
| 12. He contacted the website, |
| 13. and bought the iphone that he wanted so much. |
| 14. He was so happy that he organized a party. |

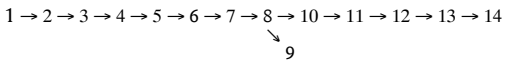


**Figure 1.** Casual Chain Representation of the Sample Story in Table 1.

It can be observed that statement 4 is in the causal chain, given that it has a cause (statement 3) and a consequence (statement 5). Statement 9 represents a dead-end, given that it has a cause (statement 8) but not a consequence.

## Empirical Findings and Applications of the Model to Education and Learning

Empirical studies have found that statements that are on the causal chain tend to be recalled more frequently (Black & Bower, 1980; Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985), more often included in summarization protocols (Trabasso & van den Broek, 1985), and judged to be more important (Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985) than statements that are dead-ends by college students.

Another set of studies found that the same events are recalled more frequently by college students when they are part of the causal chain than when they are dead-ends (Omanson, 1982).

The tools of the model have also been applied to the study of the comprehension of children. Results of these studies suggest that elementary school children recall statements that are part of the causal chain more frequently than statements that are dead-ends for age-appropriate stories (Goldman & Varnhagen, 1986; Stein & Glenn, 1979; Trabasso et al., 1984; Wolman, 1991).

To summarize, this model highlights the importance of the study of the role of the establishment of causal connections in discourse comprehension. Yet, it has a number of limitations. First, it provides an intuitive definition of causality. That is, it does not provide explicit criteria to identify causal connections among statements. A second limitation is that each statement in the causal chain can have at most one cause and one consequence (van den Broek, 1990, 1994).

## Causal Network Model

The Causal Network Model (Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985) overcomes the limitations of the Causal Chain Model. It provides explicit criteria to establish whether a causal connection can be inferred between two statements, and highlights that statements can have multiple causes or consequences.

According to the model, there are three criteria for identifying causal connections. These are based on philosophical (Hume 1739/1964; Mackie, 1980) and legal theories of causality (Hart & Honoré, 1985). The temporal priority criterion suggests that a cause never occurs after the consequence. The operativity criterion suggests that the cause needs to be active when the consequence occurs (for example, goals are active when a protagonist attempts to attain them). According to the necessity criterion, the cause needs to be necessary for the consequence to occur. That is, one must be able to state that if the event that is considered the cause had not happened, then the event that represents the consequence would not have happened). For example, in *The call of the wild* (London, 1903), the author describes the protagonist's experiences:

1. Every hour was filled with shock and surprise.
2. He had been flung into the heart of things primordial.

In this case, it can be proposed that statement 2 causes statement 1, because the protagonist's "being flung into the heart of things primordial" occurs prior to his "every hour being filled with shock and surprise", is in operation when it does, and is necessary for it to happen. The model also proposes that if event A is necessary for B, and event B is necessary for event C, then event A is necessary for event C, consistent with the notion of *transitivity* (Lewis, 1973).

Four types of causal connections are identified by the model: motivation (which connects a a goal and an attempt to attain it), psychological causation (which connects an event and the internal

reaction that it generates), physical causality (which connects and event and the changes in the physical state of people or objects that it generates), and possibilitation (which connects events that are necessary but not sufficient for other events to occur).

The model also highligths that single statements can have multiple causes or consequences. As a result, it allows researchers to examine the role that the total number of causal connections a statement has, or its causal connectivity plays in comprehension.

Once the causal connections among the statements are identified, they are depicted in a causal network representation. Figure 1 presents the network for the story in Table 1, with nodes indicating the statements and lines indicating the causal relations.

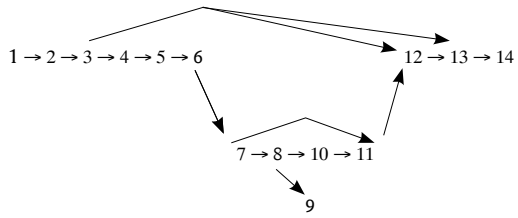


**Figure 2.** Casual Network Representation of the Sample Story in Table 1.

## Empirical Findings and Applications of the Model to Education and Learning

Trabasso, van den Broek, and Suh (1989) examined whether the model's criteria are consistent with readers' notions of causality. With this aim, they asked a group of college students to read a series of stories, and to estimate the strength of the causal connections between some pairs of statements. Results indicated that the judged causal relation was high when all criteria were met, and it decreased when one of them was not (especially, the temporal priority criterion). Also, they judged two statements that were connected through a series of causal connections to be more related than two unrelated statements, supporting the notion of transitivity.

Another set of studies examined the role of causal connnectivity in the construction of the product of comprehension. Their results suggest that events with more connections are rated as more important (Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985), included more often in summaries (van den Broek & Trabasso, 1986), and recalled more often and more quickly (Goldman &Vernhagen, 1986; O'Brien & Myers 1987; Radvansky, Tamplin, Armendarez, & Thompson, 2014) than are events with fewer connections.

The tools of the model have been applied to the study of the development of comprehension. Results of these investigations suggest that children establish causal connections at a young age, before formal reading education starts (Kendeou, Bohn-Gettler, White, & van den Broek, 2008; Kendeou et al., 2014; McMaster et al., 2014; van den Broek, 1989; van den Broek & Helder, 2017). For example, 4-year-old children tend to remember statements that have a high number of causal connections more often than those that have a low number of them (Kendeou, van den Broek, White, & Lynch, 2009). At the same time, older children are better able to establish causal connections among statements than younger children (Beker, Jolles, & van den Broek, 2017; Lynch et al., 2008; Pavias, van den Broek, Hickendorff, Beker, & van Leijenhorst, 2016; van den Broek, 1989, 1997; van den Broek, Helder, & van Leijenhorst, 2013; van den Broek, Lorch, & Thurlow, 1996). For example,7-year-old children establish a greater number of these connections than 4-year-old children (Thompson & Myers, 1985).

Considering these results, researchers have developed interventions that aim to focus the attention of these young comprehenders on the most causally connected events. These involve the presentation of audiovisual materials (such as drawings and televised stories), and the generation of causal questions that promote the monitoring of causal breaks (sections of the material where the comprehender needs to establish causal connections). Empirical findings suggest that these interventions facilitate comprehension (McMaster et al. 2012; Mokhtari & Reichard, 2002). Other studies have suggested that the establishment of a high number of causal connections also facilitates the comprehension of students with learning disabilities (Espin, Cevasco, van den Broek, Baker, & Gersten, 2007; Kendeou et al., 2014; McMaster et al., 2012).

Another line of research has examined the effect of the implementation of text revision procedures in the promotion of the comprehension of expository texts by highschool and college students. These procedures include the Causal-Temporal Method (which can be applied to History texts; Linderholm et al., 2000) and the Increasing Coherence Relations Procedure (which can be applied to any expository text; Vidal-Abarca et al., 2002). These procedures involve adding new statements to original texts, which increase the average number of causal connections, and allow for the integration of isolated and distant statements. Results of studies that have examined the effect of these revisions suggest that they promote question-answering and recall by highschool and college students (Barreyro, Molinari, Bechis, & Cevasco, 2012; Cevasco & de Simone, 2016; Linderholm, Virtue, Tzeng, & van den Broek, 2004; Vidal-Abarca, Martínez, & Gilabert, 2000; Vidal-Abarca et al., 2002).

A third line of research has examined the role of the causal connectivity of the statements in the comprehension of narrative and expository spoken discourse. Examining the comprehension of discourse presented in this modality is important, given that most studies in comprehension have focused on written discourse (Cevasco & van den Broek, 2013, 2017; Ferreira & Anes, 1994; Fraundorf & Watson, 2011). Results of these studies indicate that spoken statements that have a high number of causal connections facilitate recall and question-answering by highschool and college students (Cevasco, 2010; Cevasco & Muller, 2009; Cevasco, Muller, & Bermejo, 2017, 2018; Cevasco & van den Broek, 2008; Gaviria & Cevasco, 2012). These findings suggest that it could be useful for instructors to establish a high number of these connections among statements as they teach, in order to promote student learning.

One limitation of this model is that it focuses on the product of reading comprehension, but not on the processes that take place during the discourse comprehension. This is important because, even though it contributes to the study of how the outcome of comprehension is constructed, it does not explore the cognitive activities involved in the establishment of causal connections during discourse comprehension.

## Causal Inference Maker Model

The Causal Inference Maker Model (van den Broek, 1990, 1994) examines the cognitive processes that take place during discourse comprehension. It integrates the central notions of the Causal Network Model with research concerning the role of the limitations in the capacity of working memory and attentional resources to model the actual coherence building processes that take place during comprehension.

According to the model, as the reader procedes through the text, he or she attempts to obtain adequate causal justification for each statement. The first statement to be considered is the immediately preceding one. If it fulfills the criteria, the reader generates a *connecting inference*. For example (van den Broek, 1994):

The man accidentaly dropped the crystal glass.

The glass broke.

INFERENCE: The glass broke because the man dropped it.

If the prior statement does not fulfill the criteria, then a coherence break occurs. This break results in a search for information, and there are two potential sources. One of them involves the reactivation of one or more prior statements. In this case, the comprehender generates a *reinstatement inference.* For example:

John's brother beat him.

John told his parents.

The following day, John's body was covered with bruises.

INFERENCE: John's body was covered with bruises, because his brother beat him.

A second source of information involves the generation of *elaborative inferences.* These inferences involve the activation of the reader's background knowledge. For example (Singer, Halldorson, Lear, & Andrusiak, 1992):

Dorothy poured water on the fire.

The fire went out.

INFERENCE: Water extinguishes fire.

Connecting, reinstantement and elaborative are *backward inferences,* given that they connect the statement that the comprehender is processing to prior statements. The model also proposes that readers generate *forward inferences.* These inferences create expectations about what will happen in the text. They are not necessary for comprehension, but they can facilitate the processing of upcoming events. The model distinguishes two types: *predictive* and *anticipation of the future importance of prior events.* Predictive inferences involve the activation of background knowledge in order to anticipate upcoming events. For example (McKoon & Ratcliff, 1989):

While shooting a film, the actress accidentally fell out the 14th floor window.

INFERENCE: The actress died.

The anticipation of the future importance of prior events inferences involve the anticipation that a current statement will play a role in upcoming parts of the text, which leads the comprehender to maitain this information actíve. For example, the comprehender could maintain the *goals* of the protagonist active, because he or she anticipates that they will lead to *attempts* to attain them.

## Empirical Findings and Applications of the Model to Education and Learning

Bloom, Fletcher, van den Broek, Reitz, and Shapiro (1990) examined the generation of *connecting* and *reinstatement inferences.* They asked a group of college students to read a set of stories online. They found that reading times increased when the statement was causally connected to prior statements. The authors proposed that the time increases because the comprehender is generating the inference. Also interested in the generation of these inferences, van den Broek and Lorch (1993) observed that a statement was recognized faster by college students when it was re-presented preceded by an event to which it was causally connected, than when it was preceded by an unrelated statement. These results suggest that the generation of the causal inference facilitates recognition. Similar results were found by Trabasso and Suh (1993), and Dopkins, Klin, and Myers (1993) with a recognition task and by more recent studies (Barreyro et al., 2012; Bohn-Gettler & Rapp, 2011; Pérez, Paoleri, Macizo, & Bajo, 2014; van den Broek, Rohleder, & Narvaez, 1996).

The generation of elaborative inferences was examined by Singer et al. (1992). They asked college students to read pairs of statements, which were causally connected, and were then asked questions about background knowledge. For example:

Dorothy poured water on the fire.

The fire went out.

QUESTION: Does water extinguish fire?

Results indicated that students answered more quickly when the questions followed sentence pairs that required the activation of this information than when they read pairs did not. Similar results were found by other question-answering studies (Singer et al., 1992; Singer, Revlin, & Halldorson, 1990), and by more recent studies (Barreyro et al., 2012; Bohn-Gettler & Rapp, 2011; Pérez et al., 2014; van den Broek et al., 1996).

Other studies have examined the generation of predictive inferences. Their results suggest that the causal sufficiency of the event has a role in the likelihood that these inferences are generated. For example, if comprehenders are presented with statements such as (McKoon & Ratcliff, 1989):

While shooting a film, the actress accidentally fell out the 1st floor window.

While shooting a film, the actress accidentally fell out the 14th floor window.

PREDICTIVE INFERENCE: The actress died.

Results of naming tasks suggest that the inference is more available following statements that provide high causal sufficiency such as 2 than statements that provide weak sufficiency such as 1 (Murray, Klin, & Myers, 1993). Other studies have suggested that individual differences and prior context play an important role in the generation of these inferences (Barreyro et al., 2012; Calvo, 2000; Linderholm, 2002; McNamara & Magliano, 2009; Pérez et al., 2014).

The generation of anticipation of the relevance of prior events inferences was examined by van den Broek, Fletcher, and Marsolek (1989). These authors asked a group of college students to read story stems, and to provide continuation sentences. Results indicated that the continuations tended to be causally connected to the events described in the story stems. These findings suggest that the establishment of causal connections has a strong influence on the expectations of the comprehenders. Duffy (1986) found similar results.

The tools of the model have been applied to the study of the development of comprehension. Results from these studies suggest that older children are able to generate inferences that connect larger parts of the text (such as paragraphs, episodes, etc), and to infer abstract connections (such as between topics, and between story events and the emotions of the characters) to a greater extent than younger children (Diergarten & Nieding, 2015; Kendeou et al., 2009; Mouw, van Leijenhorst, Saab, Danel, & van den Broek, 2017; Rapp, van den Broek, McMAster, Kendeou, & Espin, 2007; van den Broek, 1997; van den Broek, White, Kendeou, & Carlson, 2009)[2]. For example, 7-year-old children generate a higher number of inferences than 4-year-old children (Thompson & Myers, 1985).

The application of the tools of the model has allowed researchers to identify *profiles of struggling readers.* Results of think aloud and eye-movement studies suggest that they can be grouped in *paraphrasers* and *elaborators* (Karlsson et al., 2018; McMaster et al., 2012; Seipel, Carlson & Clinton, 2017). Paraphrasers are readers that tend to paraphrase or repeat the information in the text, but not to generate inferences. Elaborators are readers that tend to generate elaborative inferences, but that tend to be inaccurate or invalid according to the information in the text. The identification of these profiles has allowed researchers to develop interventions to promote the comprehension of these readers. These involve the design and generation of *causal questions* (such as 'Why did Pedro decide to get a paper route?' related to the story in Table 1, which prompt the comprehender to connect the current statement with specific prior statements) and *general questions* (such as 'How does this statement relate to earlier parts of the text?', which prompt comprehenders to make any connections between the current statement and prior statements). Empirical findings suggest that the inclusion of these questions facilitates recall by both groups of readers (McMaster et al., 2012). They also suggest that causal questions facilitate the recall of elaborators to a greater extent. It is possible that, given that these questions require

the comprehender to make specific text-based connections, they facilitate that these readers focus on important information within the text. In turn, the presentation of general questions facilitates the comprehension of paraphrasers to a greater extent. It is possible that, given that these questions prompt the comprehender to make any text-based connection, they help these readers think about the text beyond the current sentence. Research has also proposed other readers' profiles (such as literal readers, who predominantly repeat the literal text when asked to think aloud; Karlsson et al., 2018; Kraal, Koornneef, Saab, & van den Broek, 2017). Future research will allow us to discover new profiles, and finer distinctions within existing profiles.

Other studies have investigated the generation of causal inferences during the comprehension of spontaneous spoken discourse by college students. Cevasco (2009) examined the role of the presence of discourse markers in the generation of reinstatement inferences during the comprehension of narrative spoken discourse. Results indicated that the presence of the discourse marker facilitated the reactivation of prior causally connected statements. Cevasco and van den Broek (2016) observed that the presence of filled pauses (such as 'uh') had a negative effect on the recognition of spoken words, but not on the generation of causal inferences. These results suggest that the generation of these inferences plays a role in the processing of spoken discourse by college students.

A limitation of this model is that it does not examine the interplay between the cognitive processes and the result of comprehension. This is important, because it does not allow us to examine how passive and strategic inferential processes interplay in the construction of a coherent discourse representation.

## Landscape Model

The Landscape Model (Linderholm et al., 2004; van den Broek, Young, Tzeng, & Linderholm, 1999) is a computational model designed to capture the interplay between the processing of causal connections and the construction of a coherent representation of discourse in memory.

The model proposes that the activation of units (which can be statements, propositions, concepts, etc.) fluctuates as the reader proceeds through the text. In each reading cycle, there are four possible sources of activation: 1) the text that the reader is processing (which has the highest level of activation), 2) the preceding reading cycle, 3) the reinstatement of one or more prior cycles, and 4) the reader's background knowledge. The reactivation of prior cycles and the activation of the reader's prior knowledge involve the generation of inferences. The model contemplates, following the Causal Inference Maker model, the generation of *connecting, reinstatement* and *elaborative inferences.* Considering these sources of activation, in each reading cycle new statements are activated, and activation values of current statements change. In addition, the co-activation of statements leads to the establishment of connections between them. Through these fluctuating activations, a memory representation of the text gradually and dynamically emerges.

Two types of mechanisms guide access to these sources of informatiton. The first type is *cohort activation.* The model assumes that when a concept is activated, all other concepts that are activated become associated with it. Thus, each concept connects with other concepts to form a cohort. In turn, when one or more of the individual concepts in a cohort become active, the other concepts are also activated. The amount of activation for the secondarily retrieved propositions is a function of the strength of their relation to the primarily retrieved statement, and the amount of activation of the primarily activated statement. This mechanism is passive and similar to the activation mechanism described by memory-based views such as the Resonance Model (Myers & O'Brien, 1998; O'Brien & Myers, 1999; O'Brien, Rizzella, Albrecht, & Halleran, 1998).

The second mechanism is *coherence-based retrieval.* This is a strategic mechanism by which information is retrieved with the aim of meeting a reader's standards of coherence or goals (van den Broek & Helder, 2017). These standards reflect a reader's knowledge and beliefs about what constitutes good comprehension, as well as his or her specific goals for reading the particular text (e.g., study, entertainment). For narratives, referential and causal standards of coherence are central (Linderholm et al., 2004; van den Broek, Lorch, Linderholm, & Gustafson, 2001). Referential coherence is obtained when the reader is able to identify the reference for the objects, persons, etc, that are part of the sentence that he or she is reading. Causal coherence is obtained when the reader is able to find causal explanation for the event described in the current sentence. The model allows for the implementation of other standards of coherence.

The simulation of comprehension includes three stages. In the first stage, the activation values for each statement are calculated through an analysis of the materials, according to the theoretical model of the researcher. In the second stage, the model processes the input values cycle by cycle and produces an activation matrix that represent the state of working memory after reading each sentence. In the third stage, the model establishes and updates the connections of the emergent network memory representation. The output indicates the strength of the connections among statements at each reading cycle, and the node strength of each statement (that is, their total activation across reading cycles).

## Empirical Findings and Applications of the Model to Education and Learning

In order to examine the psychological validity of the model, van den Broek, Risden, Fletcher, and Thurlow (1996) asked a group of college students to read a series of narratives, and to estímate how active they considered that each concept was after reading each sentence. They implemented the referential and causal standards of coherence. Results indicated a high correlation between the predictions of the model and the estimations that readers provided. In other words, those concepts that had high node strength tended to be recalled more frequently and to be recalled first than those that had low node strength. These results provided empirical evidence that supported the proposals of the model. Similar results were found by van den Broek et al. (1999).

Molinari Marotto, Barreyro, Cevasco, and van den Broek (2011) applied the tools of the model to study the generation of emotion inferences during the comprehension of narrative texts by Spanish-speaking college students. Emotion inferences are elaborative inferences that involve the activation of the prior knowledge of the comprehender about emotions and their triggering conditions (Graesser, Singer, & Trabasso, 1994). In order to examine this, they implemented two alternative simulations: *causal-referential* and *causal-referential-emotional.* The causal-referential simulation implemented the referential and causal standards of coherence. The causal-referential-emotional, implemented the referential and causal standards of coherence, and the generation of emotion inferences. In other words, it assumed that the comprehender attempts to maintain referential and causal coherence, and that they generate inferences about the emotions that characters experience as a consequence of story events. Results indicated that the simulation that implemented the generation of emotion inferences provided a better fit to the recall data.

The tools of the model have also been applied to the study of the comprehension of expository discourse. Results of these studies suggest that those statements that have high node strength tend to be recalled more frequently by college students than those that have low node strength (van den Broek, Kendeou, Sung, & Cheng, 2003). In addition, the likelihood of comprehenders' identifying an

inconsistency between initial and later statements depends on the activation that the initial information received in previous reading cycles, how strongly it was connected to other statements, and the extent to which the later information semantically overlapped with the inconsistent text information (Linderholm et al., 2004; van den Broek et al., 1999).

Landscape model applications to knowledge acquisition and, in particular, to the correction of students' misconceptions have also been examined. These studies suggest that the presentation of texts that explicitly co-activate the misconceptions that readers tend to have about a topic and the correct ideas (which are called *refutation texts,* Guzzetti, Snyder, Glass, & Gamas, 1993) facilitates the revision of the incorrect idea to a greater extent than the presentation of classic expository texts (van den Broek & Kendeou, 2008).

Other studies have focused on the role of comprehension goals. Linderholm et al. (2004) observed that a simulation that implemented a *study goal* resulted in more overall activation, and activation of more concepts, than did a simulation that implemented an *entertainment goal.* In particular, the main ideas of the text received more activation in the study simulation than in the entertainment simulation. Comparisons of these results to think-aloud protocols showed that college students tended to recall highly connected statements to a greater extent in the study simulation than the entertainment simulation, suggesting that the model captures readers' adjustment of inferential processes as a function of reading goal.

The comprehension of news (Blanc, Kendeou, van den Broek, & Brouillet, 2008), and the application of the model's tools to discourse analysis (Yeari & van den Broek, 2016) have also been examined. Results of these studies suggest that the model provides useful tools to examine how college students update information in the presence of alternative causal explanations while reading news reports, and how text structure and reader characteristics (e.g., background knowledge, standards of coherence, etc.) interact during readers' text interpretation.

One possible limitation of the model is that, although background knowledge is presumed to be an integral part of the fluctuating activations, it is not included. This is a limitation when one wants to examine the role of individual differences in the reader's understanding of the text. Yet, recent extensions of the model are including this variable as a pre-reading associative network, capturing its influence on discourse comprehension (Yeari & van den Broek, 2016).

## Discussion

The aim of this paper is to review the contributions that four models that examine the establishment of causal connections have made to the study of the comprehension of discourse, and the promotion of student learning: the Causal Chain Model, the Causal Network Model, the Causal Inference Maker, and the Landscape Model. With this aim, the central notions of these models, empirical findings that support their psychological validity, and applications of their tools to the facilitation of student learning were presented.

These models highlight that successful comprehension depends on the construction of a coherent mental representation of the text in memory. This applies to narrative and expository discourse and in both written and spoken form. This mental representation consists of a network of meaningful causal relations, in which those statements that have a high number of these connections play a central role. The described models also suggest that comprehenders generate inferences as they read, which involve the reactivation of prior statements and students' background knowledge. The generation of these inferences contributes to the integration of statements, and the facilitation of discourse processing. Another contribution of the models has been to highlight that, as readers process texts, statements fluctuate in activation, and passive and coherence-based processes interplay.

Considering the proposals of the models, recommendations for educators to improve student learning by promoting discourse comprehension can be made. These can be useful for the design and selection of materials and for teaching best practices. Among them, the presentation of audiovisual materials can be used to implement interventions that promote the establishment of causal connections by young children, or by children who have reading difficulties. For example, the teacher can present drawings and/or televised stories, and pose questions that focus students' attention on the most causally connected statements. In addition, he or she can present written materials that allow for the establishment of a high number of causal connections among statements. In order to find these materials, teachers can identify causal connections among statements in the candidate texts, following the criteria proposed by the Causal Network Theory. These criteria would allow them to establish if a specific text has a high number causal connections. In turn, considering the important role that statements that have a high number of causal connections play in comprehension, it would be important for the instructor to include these main ideas in the written materials (such as handouts, or Power-Point presentations) that he or she presents during the class, and to establish a high number of these connections among spoken statements as they teach. The inclusion of *causal* and *general* questions in the texts and the accompanying spoken lesson would also contribute to the promotion of the generation of elaborative inferences during the processing of the educational materials. In other words, the described models provide useful tools to identify what are good questions to ask students and when to ask them during the presentation of educational materials, in order to promote the construction of causal discourse coherence. Other approaches to reading instruction have focused on the role of other variables in discourse comprehension, such as the promotion of reading comprehension strategies and metacognitive processes (these interventions involve explicitly teaching students to use metacognitive strategies, through tasks such as self-questioning, self-explanation, and self-monitoring of comprehension; Borkowski, Weyhing, & Carr, 1988; Gersten, Fuchs, Williams, & Baker, 2001; Malone & Mastropieri, 1992; McCrudden & Kendeou, 2014; McNamara, 2004, 2007; Rapp et al., 2007), the promotion of the activation of background knowledge (these interventions involve promoting the use of prior knowledge, by presenting text previews to the students, and vocabulary and information relevant to the text prior to reading; Elbro & Buch-Iversen, 2013; Sachs, 1983; Snider, 1989), and the improvement of knowledge about text structure (these interventions provide students with strategies for reading specific types of texts, by using charts or diagrams, and by teaching them to identify particular organizational structures; Gersten et al., 2001; Linderholm et al., 2000; Meyer & Ray, 2011; Williams et al., 2007, 2014)[3]. Considering the characteristics of the reader, the properties of text and the instructional context, the instruction can consider combining these interventions in order to facilitate the learning of students with different reading profiles.

In addition, if the instructor believes that students have misconceptions about a specific topic, it could be helpful for him or her to explicitly co-activate these incorrect ideas with the correct ideas, in order for students to revise them. This could be done by combining presentation modalities. For example, teachers can present refutation texts for students to read, but also explicitly coactivate the correct and incorrect ideas in spoken discourse. In turn, given that comprehension goals have been found to facilitate the recall of main ideas, it would be useful for instructors to promote that students establish them. This could be done by assigning tasks that are focused on the monitoring of these ideas.

For example, students can be told that they will be asked to complete an assignment focused specificly on the recall of these ideas after the class. Other measures of comprehension that can be used by educators include think-aloud protocols (in which the student expresses what comes to mind as each statement or idea that is part of a text is comprehended; Ericsson & Simon, 1984; Karlsson et al., 2018; Rapp et al., 2007. This measure allows the teacher to examine the generation of inferences during the processing of discourse. For example, a student can be presented with a text that promotes the generation of causal inferences, and be asked to think out aloud after specific statements, in order to examine whether he or she is generating the expected inference), summarization tasks (which require the student to provide a summary of the main or most important ideas of the text; Horiba, 2000; Rapp et al., 2007. This task allows the teacher to examine whether the student has identified the most central ideas of the text, and included them in the mental representation that he or she constructed), and judgments of importance (which require students to judge or rate how important or central they consider the role of statements that were part of the text to be; Alexander, Kulikowich, & Schulze, 1994; Trabasso & Sperry, 1985. This task allows the teacher to examine whether students are able to identify the main or most important ideas of the text, and distinguish them from the less central ideas). These tasks have been successfully used by prior studies to study comprehension (Karlsson et al., 2018; Radvansky et al., 2014; Rapp et al., 2007; Trabasso & Sperry, 1985; Trabasso & Suh, 1993), and can provide useful tools to the teacher to measure the effect of his or her instruction strategies on student learning, The consideration of these recommendations and a combination of these measures is expected to provide tools to educators to promote that students monitor their comprehension, generate inferences, and construct a coherent representation of the topics of the class.

In conclusion, models on causality processing have contributed to our understanding of how students learn from educational materials. Given that they highlight the importance of the promotion of the establishment of meaningful connections for the facilitation of narrative and expository discourse comprehension, they provide useful tools to educators to develop procedures to revise the structure of texts, and to design educational interventions.

The continuity of these lines of research and the development of new ones will allow us to gain more knowledge on how we can promote succesful learning by students of different ages who speak different languages.

## Conflict of Interest

The authors of this article declare no conflict of interest.

## Acknowledgement

We thank Jeffrey Ruha for his feedback on an earlier version of this article.

## Notes

[1]For other models that have examined the role of the processing of causality in discourse comprehension, such as the Event-Indexing Model, see Zwaan, and Rapp (2006). For a review of discourse comprehension models, see McNamara and Magliano (2009).

[2]For other interventions that promote discourse comprehension, see Rapp et al. (2007) and van den Broek and Helder (2017).

[3]The described interventions are focused on readers' higher-order processes. Other interventions have focused on the promotion of basic skills, such as word training (Tan & Nicholson, 1997) and vocabulary instruction (Pany, Jenkins, & Schreck, 1982).

## References

Alexander, P. A., Kulikowich, J. M. & Schulze, S. K. (1994). How subject-matter knowledge affects recall and interest. *American Educational Research Journal, 31*, 313- 337. https://doi.org/10.3102/00028312031002313

Barreyro, J. P., Molinari Marotto, C., Bechis, S., & Cevasco, J. (2012). Comprensión de textos expositivos y métodos sistemáticos de revisión de textos: el efecto del incremento de la densidad de relaciones y la repetición de términos. *Investigaciones en Psicología, 17,* 9-24.

Beker K., Jolles, D. & van den Broek, P. W. (2017). Meaningful learning from texts: The construction of knowledge representations. In J. A. León & I. Escudero (Eds.), *Reading comprehension in educational settings. Book series: Studies in written language and literacy no. 16.* Amsterdam, The Netherlands: John Benjamins Publishing Company. 29-62. https://doi.org/10.1075/swll.16.02bek

Black, J. B., & Bower, G. H. (1980).Story understanding as problem solving. *Poetics, 9*, 223-250. https://doi.org/10.1016/0304-422X(80)90021-2

Blanc, N., Kendeou, P., van den Broek, P. W., & Brouillet, D. (2008). Updating situation models during reading of news reports: Evidence from empirical data and simulations. *Discourse Processes, 45*, 103-121. https://doi.org/10.1080/01638530701792784

Bloom, C. P., Fletcher, C. R., van den Broek, P., Reitz, L., & Shapiro, B. P. (1990). An on-line assessment of causal reasoning during comprehension. *Memory and Cognition, 18,* 65-71. https://doi.org/10.1023/A:1014957628672

Bohn-Gettler, C. M., & Rapp, D. N. (2011). Depending on my mood: Mood-driven influences on text comprehension. *Journal of Educational Psychology, 103*, 562-577. https://doi.org/10.1037/a0023458

Borkowski, J. G., Weyhing, R. S., & Carr, M. (1988). Effects of attributional retraining on strategy-based reading comprehension in learning-disabled students. *Journal of Educational Psychology, 80, 46-53.* https://doi.org/10.1037/0022-0663.80.1.46

Calvo, M. G. (2000). The time course of predictive inference depends on contextual constraints. *Language and Cognitive Processes, 15,* 293-319. https://doi.org/10.1080/016909600386066

Cevasco, J. (2009). The role of connectives in the comprehension of spontaneous spoken discourse. *Spanish Journal of Psychology, 12,* 56-65. https://doi.org/10.1017/S1138741600001475

Cevasco, J. (2010). El interjuego entre los temas de conversación y la conectividad causal de los enunciados conversacionales en el recuerdo del discurso oral espontáneo. *Perspectivas en Psicología, 7,* 1-7.

Cevasco, J., & de Simone, J. (2016). Facilitación de la comprensión del discurso expositivo: aportes de los estudios acerca de la introducción de cambios en los textos y del efecto de la modalidad de presentación del material. *Psicología Iztacala, 19,* 601-621.

Cevasco, J., & Muller, F. (2009). Conectividad Causal, rol conversacional y confiabilidad del hablante en el recuerdo de conversaciones. *Psicología Iberoamericana, 17*(2), 33-40.

Cevasco, J., Muller, F., & Bermejo, F. (2017). Facilitation of the comprehension of written and spoken discourse. *Psychology and Education, 14*(2), 1-9.

Cevasco, J., Muller, F., & Bermejo, F. (2018). The role of discourse marker presence, causal connnectivity and prior knowledge in the compehension of topic shifts. *Current Psychology, 37*, 1-14.

Cevasco, J., & van den Broek, P. (2008).The importance of causal connections in the comprehension of spontaneous spoken discourse. *Psicothema, 20,* 801-806.

Cevasco, J., & van den Broek, P. (2013). Studies on the establishment of connections among spoken statements: What can they contribute to the promotion of students' construction of a coherent discourse representation? *Psicología Educativa, 19,* 67-74. https://doi.org/10.1016/S1135-755X(13)70012-5

Cevasco, J., & van den Broek, P. (2016).The effect of filled pauses on the processing of the surface form and the establishment of causal connections during the comprehension of spoken expository discourse. *Cognitive Processing, 17,* 185-194. https://doi.org/10.1007/s10339-016-0755-8

Cevasco, J., & van den Broek, P. (2017). The importance of causality processing in the comprehension of spontaneous spoken discourse. *Ciencia Cognitiva, 11*(2), 43-45.

Diergarten, A. K., & Nieding, G. (2015). Children's and adults' ability to build online emotion inferences during comprehension of audiovisual and auditory texts. *Journal of Cognition and Development, 16,* 381-406. https://doi.org/10.1080/15248372.2013.848871

Dopkins, S. C., Klin, C., & Myers, J. L. (1993). Accessibility of information about goal during processing of narratives texts. *Journal of Experimental Psychology: Learning, Memory & Cognition, 19,* 70-80. https://doi.org/10.1037//0278-7393.19.1.70

Duffy, S. A. (1986). Role of expectations in sentence integration. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 208-219. https://doi.org/10.1037//0278-7393.12.2.208

Elbro, C., & Buch-Iversen, I. (2013). Activation of background knowledge for inference making: Effects on reading comprehension. *Scientific Studies of Reading, 17*, 435-452.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data.* Cambridge, MA: Bradford Books/MIT Press.

Espin, C. A., Cevasco, J., van denBroek, P., Baker, S., & Gersten, R. (2007). History as narrative: The nature and quality of historical understanding

for students with learning disabilities. *Journal of Learning Disabilities, 40,* 174-182. https://doi.org/10.1177/00222194070400020801
Ferreira, F., & Anes, M. (1994). Why study spoken language processing? In M.Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp. 33-56). San Diego, CA: Academic Press.
Fraundorf, S. H., & Watson, D. G. (2011). The disfluent discourse: Effects of filled pauses on recall. *Journal of Memory and Language, 65*, 161-175. https://doi.org/10.1016/j.jml.2011.03.004
Gaviria, G., & Cevasco, J. (2012). *El rol del cambio de la modalidad de presentación y la conectividad causal de los enunciados en la comprensión de discurso espontáneo.* Poster presentado en el IV Congreso Internacional de Investigación y Práctica Profesional en Psicología de la Universidad de Buenos Aires. Buenos Aires, Argentina.
Gersten, R., Fuchs, L. S., Williams, J. P., & Baker, S. (2001). Teaching reading comprehension strategies to students with learning disabilities: A review of research. *Review of Educational Research, 71,* 279-320. https://doi.org/10.3102/00346543071002279
Goldman, S. R., & Varnhagen, C. K. (1986). Memory for embedded and sequential story structures. *Journal of Memory and Language, 25*, 401-418. https://doi.org/10.1016/0749-596X(86)90034-3
Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101,* 371-395. https://doi.org/10.1037/0033-295X.101.3.371
Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly, 28,* 117-159. https://doi.org/10.2307/747886
Hart, H. L. A., & Honoré, A. M. (1985). *Causation in the law.* Oxford, UK: Clarendon Press. https://doi.org/10.1093/acprof:oso/9780198254744.001.0001
Horiba, Y. (2000). Reader control in reading: Effects of language competence, text type, and task. *Discourse Processes, 29*, 223-267. https://doi.org/10.1207/S15326950dp2903_3
Hume, D. (1739/1964). *A treatise of human nature.* Aalen, West Germany: Scientia Verlag. https://doi.org/10.1093/oseo/instance.00046221
Karlsson, J., van den Broek, P., Helder, A., Hickendorff, M., Koornneef, A., & van Leijenhorst, L. (2018). Profiles of young readers: Evidence from thinking aloud while reading narrative and expository texts. *Learning and Individual Differences, 67*, 105-116. https://doi.org/10.1016/j.lindif.2018.08.001
Kendeou, P., Bohn-Gettler, C., White, M. J., & van den Broek, P. (2008). Children's inference generation across different media. *Journal of Research in Reading, 31*, 259-272. https://doi.org/10.1111/j.1467-9817.2008.00370.x
Kendeou, P., van den Broek, P., Helder, A., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research and Practice, 29,* 10-16. https://doi.org/10.1111/ldrp.12025
Kendeou P., van den Broek P., White M. J., & Lynch J. S. (2009). Predicting reading comprehension in early elementary school: The independent contributions of oral language and decoding skills. *Journal of Educational Psychology 101*, 765-778. https://doi.org/10.1037/a0015956
Kraal, A., Koornneef, A. W., Saab, N., & van den Broek, P. W. (2017). Processing of expository and narrative texts by low and high-comprehending children. *Reading and Writing, 33*, 1-24.
Lewis, D. (1973). *Counterfactuals.* Cambridge, MA: Harvard University Press.
Linderholm, T. (2002). Predictive inference generation as a function of workingmemory capacity and causal text constraints. *Discourse Processes, 34,* 259-280. https://doi.org/10.1207/S15326950DP3403_2
Linderholm, T., Everson, M., van den Broek, P., Mischinski, M., Crittenden, A., & Samuels, J. (2000). Effects of causal text revisions on more- and less-skilled readers' comprehension of easy and difficult texts. *Cognition and Instruction, 18,* 525-556. https://doi.org/10.1207/S1532690XCI1804_4
Linderholm, T., Virtue, S., & Tzeng, Y., & van den Broek, P. (2004). Fluctuations in the availability of information during reading: Capturing cognitive processes using the landscape model. *Special Issue of Discourse Processes: Accessibility in Text and Discourse Processing, 37*, 165-186. https://doi.org/10.1207/s15326950dp3702_5
London, J. (1903). *The call of the wild.* New York, NY: Macmillan.
Lynch, J. S., van den Broek, P., Kremer, K. E., Kendeou, P., White, M. J., & Lorch, E. P. (2008). The development of narrative comprehension and its relation to other early reading skills. *Reading Psychology, 29,* 327-365. https://doi.org/10.1080/02702710802165416
Mackie, J. L. (1980). *The cement of the universe.* Oxford, UK: Clarendon Press. https://doi.org/10.1093/0198246420.001.0001
Malone, L. D., & Mastropieri, M. A. (1992). Reading comprehension instruction: Summarization and self-monitoring training for students with learning disabilities. *Exceptional Children, 58,* 270-279. https://doi.org/10.1177/001440299105800309
Mandler, J. M., & Johnson, N. S. (1977). Remembrance of things parsed: Story structure and recall. *Cognitive Psychology, 9*, 111-151. https://doi.org/10.1016/0010-0285(77)90006-8
McCrudden, M. T., & Kendeou, P. (2014). Exploring the link between cognitive processes and learning from refutational text. Journal of Research in Reading, 37, S116-S140.
McKoon, G., & Ratcliff, R. (1989).Semantic associations and elaborative inference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 326-338. https://doi.org/10.1037//0278-7393.15.2.326
McMaster, K. L., Espin, C. A., & van den Broek, P. (2014). Making connections: Linking cognitive psychology and intervention research to improve comprehension of struggling readers. *Learning Disabilities Research & Practice, 29*, 17-24. https://doi.org/10.1111/ldrp.12026
McMaster; K., van den Broek, P., Espin, E., White, M. J., Rapp, D., Kendeou, P., … Carlson, S. (2012). Making the right connections: differential effects of reading intervention for subgroups of comprehenders. *Learning and Individual Differences, 22*, 100-111. https://doi.org/10.1016/j.lindif.2011.11.017
McNamara, D. S. (2004). SERT: Self-explanation reading training. *Discourse Processes, 38*, 1-30. https://doi.org/10.1207/s15326950dp3801_1
McNamara, D. S. (2007). *Reading comprehension strategies: Theories, interventions, and technologies.* Mahwah, NJ: Erlbaum.
McNamara, D. S., & Magliano, J. (2009).Toward a comprehensive model of comprehension. In B. Ross (Ed.), *The psychology of learning and motivation* (pp. 297-384). New York, NY: Elsevier. https://doi.org/10.1016/S0079-7421(09)51009-2
Meyer, B. J. F., & Ray, M. N. (2011). Structure strategy interventions: Increasing reading comprehension of expository text. *International Electronic Journal of Elementary Education, 4*, 127-152.
Mokhtari, K., & Reichard, C. A. (2002). Assessing students' metacognitive awareness of reading strategies. *Journal of Educational Psychology, 94*, 249-259. https://doi.org/10.1037//0022-0663.94.2.249
Molinari Marotto C., Barreyro J. P., Cevasco J., & van den Broek P. W. (2011). Generation of emotional inferences during text comprehension: Behavioral data and implementation through the landscape model. *Escritos de Psicologia 4,* 9-17. https://doi.org/10.5231/psy.writ.2011.1803
Mouw, J. M., van Leijenhorst L., Saab N., Danel M. S., & van den Broek, P. (2017), Contributions of emotion understanding to narrative comprehension in children and adults. *European Journal of Developmental Psychology, 14,* 1-16.
Murray, J. D., Klin, C. M., & Myers, J. L. (1993). Forward inferences in narrative text. *Journal of Memory and Language, 32,* 464-473. https://doi.org/10.1006/jmla.1993.1025
Myers, J. L., & O'Brien, E. J. (1998). Accessing the discourse representation during reading. *Discourse Processes, 26,* 131-157. https://doi.org/10.1080/01638539809545042
O'Brien, E. J., & Myers, J. L. (1987). The role of causal connections in the retrieval of text. *Memory and Cognition, 15,* 419-427. https://doi.org/10.3758/BF03197731
O'Brien, E. J., & Myers, J. L. (1999). Text comprehension: A view from the bottom up. In S. R. Goldman, A. C. Graesser, & P. van den Broek (Eds.), *Narrative contprehension, causalily, and co herence: Essays inhonor of Tom Trabasso* (pp. 35-53). Mahwah, NJ: Lawrence Etlbaum Associates, Inc.
O'Brien, E. J., Rizzella, M. L., Albrecht, J. 8., & Halleran, J. G. (1998). Updating a situation model: A memory-based text processing víew. *Journal of Experimental Psychology: Learníng, Memory, and Cognition, 24*, 1200-1210. https://doi.org/10.1037//0278-7393.24.5.1200
Omanson, R. C. (1982). The relation between centrality and story category variation. *Journal of Verbal Learning and Verbal Behavior, 21,* 326-337. https://doi.org/10.1016/S0022-5371(82)90648-X
Pany, D., Jenkins, J. R., & Schreck, J. (1982). Vocabulary instruction: Effects on word knowledge and reading comprehension. *Learning Disability Quarterly, 5,* 202-215.
Pavias M., van den Broek P. W., Hickendorff, M., Beker K., & van Leijenhorst, L. (2016). Effects of social-cognitive processing demands and structural importance on narrative recall: Differences between children, adolescents, and adults. *Discourse Processes, 53,* 488-512. https://doi.org/10.1080/0163853X.2016.1171070
Pérez, A. I., Paolieri, D., Macizo, P., & Bajo, M. T. (2014). The role of working memory in inferential sentence comprehension. *Cognitive Processing, 15,* 405-413. https://doi.org/10.1007/s10339-014-0611-7
Radvansky, G., Tamplin, A., Armendarez, J., & Thompson, A. (2014). Different kinds of causality in event cognition. *Discourse Processes, 51*, 601-618.
Rapp, D. N., van den Broek, P., McMaster, K. L., Kendeou, P., & Espin, C. A. (2007). Higher-order comprehension processes in struggling readers: A perspective for research and intervention. *Scientific Studies of Reading, 11,* 289-312. https://doi.org/10.1080/10888430701530417
Sachs, A. (1983). The effects of three prereading activities on learning disabled students' reading comprehension. *Learning Disability Quarterly, 6*, 248-251. https://doi.org/10.2307/1510434
Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures.* Hillsdale, NJ: Erlbaum.
Seipel, B., Carlson, S. E., & Clinton, V. E. (2017). When do comprehender groups differ? A moment-by-moment analysis of think-aloud protocols of good and poor comprehenders. *Reading Psychology, 38*, 1-32. https://doi.org/10.1080/02702711.2016.1216489
Singer, M., Halldorson, M., Lear, J. C., & Andrusiak, P. (1992). Validation of causal bridging inferences. *Journal of Memory and Language, 31*, 507-524. https://doi.org/10.1016/0749-596X(92)90026-T

Singer, M., Revlin, & Halldorson, M. (1990). Bridging inferences and Enthymemes. In A. C. Graesser & G. H. Bowers (Eds.), *Inferences and text comprehension* (pp. 35-51). San Diego, Ca: Academic Press. https://doi.org/10.1016/S0079-7421(08)60247-9

Snider, V. E. (1989). Reading comprehension performance of adolescents with learning disabilities. *Learning Disability Quarterly, 12,* 87-96. https://doi.org/10.2307/1510724

Sparks, J. R., & Rapp, D. N. (2010). Discourse processing: Examining our everyday language experiences. *Wiley Interdisciplinary Reviews: Cognitive Science, 1,* 371- 381. https://doi.org/10.1002/wcs.11

Stein, N. L., & Glenn, C. G. (1979). An analysis of story comprehension in elementary school children. In R. Freedble (Ed.), *Multidisciplinary approaches to discourse comprehension* (pp. 53-120). Hillsdale, NJ: Erlbaum.

Tan, A., & Nicholson, T. (1997). Flashcards revisited: Training poor readers to read words faster improves their comprehension of text. *Journal of Educational Psychology, 89*, 276-288.

Thompson, J. G., & Myers, N. A. (1985). Inferences and recall at ages four and seven. *Child Development, 56,* 1134-1144. https://doi.org/10.2307/1130228

Trabasso, T., Secco, T., & van den Broek, P. (1984).Causal cohesion and story coherence. In H. Mandl, N. L. Stein, & T. Trabasso (Eds.), *Learning and comprehension of text* (pp. 83-111). Hillsdale, NJ: Lawrence Erlbaum Associates.

Trabasso, T., & Sperry, L. L. (1985).Causal relatedness and importance of story events. *Journal of Memory and Language, 24*, 595-611. https://doi.org/10.1016/0749-596X(85)90048-8

Trabasso, T., & Suh, S. Y. (1993). Understanding text: Achieving explanatory coherence through on-line inferences and mental operations in working memory. *Discourse Processes, 16,* 3-34. https://doi.org/10.1080/01638539309544827

Trabasso, T., & van den Broek, P. (1985). Causal thinking and the representation of narrative events. *Journal of Memory and Language, 24,* 612-630. https://doi.org/10.1016/0749596X(85)90049-X

Trabasso, T., van den Broek, P., & Suh, S. Y. (1989). Logical necessity and transitivity of causal relations in stories. *Discourse Processes, 12,* 1-25. https://doi.org/10.1080/01638538909544717

van den Broek, P. (1989). Causal reasoning and inference making in judging the importance of story statements. *Child Development, 60*, 286-297. https://doi.org/10.2307/1130976

van den Broek, P. (1990). The causal inference maker: Towards a process model of inference generation in text comprehension. In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 423-445). Hillsdale, NJ: Erlbaum.

van den Broek, P. (1994). Comprehension and memory of narrative texts: Inferences and coherence. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 539-588). San Diego, CA: Academic Press.

van den Broek, P. (1997). Discovering the cement of the universe: The development of event comprehension from childhood to adulthood. In P. van den Broek, P. W. Bauer, & T. Bourg (Eds.), *Developmental spans in event comprehension and representation* (pp. 321-342). Mahwah, NJ: Lawrence Erlbaum Associates.

van den Broek, P. (2010). Using texts in science education: cognitive processes and knowledge representation. *Science, 328,* 453-456. https://doi.org/10.1126/science.1182594

van den Broek, P., Fletcher, C. R., & Marsolek, C. J. (1989). *Cognitive processes in the composition of narrative texts: The role of causal reasoning.* Paper presented at the annual meeting for the American Educational Research Association. San Francisco, CA.

van den Broek, P., & Helder, A. (2017). Cognitive processes in discourse comprehension: Passive processes, reader-initiated processes, and evolving mental representations. *Discourse Processes, 54,* 1-13.

van den Broek, P., Helder, A., & van Leijenhorst, L. (2013). Sensitivity to structural centrality: Developmental and individual differences in reading comprehension skills. In M. A. Britt, S. R. Goldman, & J. F. Rouet (Eds.), *Reading: From words to multiple texts* (pp. 132-146). New York, NY: Routledge, Taylor & Francis Group.

van den Broek, P., & Kendeou, P. (2008). Cognitive processes in comprehension of science texts: The role of co-activation in confronting misconceptions. *Applied Cognitive Psychology, 22*, 335-351. https://doi.org/10.1002/acp.1418

van den Broek, P., Kendeou, P., Sung, Y. C., & Chen, M. (2003). *Comprehension and memory of science texts: A simulation using the Landscape Model.* Paper presented at the Annual Meeting of the Society for Text and Discourse. Madrid, Spain.

van den Broek, P., & Lorch, R. F. (1993). Network representations of causal relations in memory for narrative texts: Evidence from primed recognition. *Discourse Processes, 16*, 75-98. https://doi.org/10.1080/01638539309544830

van den Broek, P., Lorch, R. F., Linderholm, T., & Gustafson, M. (2001). The effects of readers' goals on inference generation and memory for texts. *Memory & Cognition, 29,* 1081-1087. https://doi.org/10.3758/BF03206376

van den Broek, P., Lorch, E. P., & Thurlow, R. (1996). Children's and adults' memory for television stories: The role of causal factors, story-grammar categories, and hierarchical level. *Child Development, 67,* 3010-3028. https://doi.org/10.1111/j.1467-8624.1996.tb01900.x

van den Broek, P., Risden, K. C., Fletcher, C. R., & Thurlow, R. (1996). A "landscape" view of reading: Fluctuating patterns of activation and the construction of a stable memory representation. In B. K. Britton & A. C. Graesser (Eds.), *Models of understanding text* (pp. 165-187). Mahwah, NJ: Lawrence Erlbaum.

van den Broek, P., Rohleder, L., & Narvaez, D. (1996). Causal inferences in the comprehension of literary texts. In R. J. Kreuz & M. S. MacNealy (Eds.), *Empirical approaches to literature and aesthetics* (pp. 179-200). Norwood, NJ: Ablex.

van den Broek, P., & Trabasso, T. (1986). Causal network versus goal hierarchies in summarizing text. *Discourse Processes, 9,* 1-15. https://doi.org/10.1080/01638538609544628

van den Broek P., White M. J., Kendeou, P., & Carlson S. (2009). Reading between the lines. Developmental and individual differences in cognitive processes in reading comprehension. In R. K. Wagner, C. Schatschneider, & C. Phythian-Sence (Eds.), *Beyond decoding. The behavioral and biological foundations of reading comprehension.* New York, NY: The Guilford Press. 107-123.

van den Broek, P., Young, M., Tzeng, Y., & Linderholm, T. (1999). The landscape model of reading: Inferences and the online construction of memory representation. In H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 71-98). Mahwah, NJ: Lawrence Erlbaum.

Vidal-Abarca, E., Martínez, G., & Gilabert, R. (2000). Two procedures to improve instructional text: Effects on memory and learning. *Journal of Educational Psychology, 92,* 107-116. https://doi.org/10.1037/0022-0663.92.1.107

Vidal-Abarca, E., Reyes, H., Gilabert, R., Calpe, J., Soria, E., & Graesser, A. C. (2002). ETAT: Expository text analysis tool. *Behavior Research Methods, Instruments and Computers, 34,* 93-107. https://doi.org/10.3758/BF03195428

Williams, J. P., Nubla-Kung, A. M., Pollini, S., Stafford, K. B., Garcia, A., & Snyder, A. E. (2007). Teaching cause-effect text structure through social studies content to at-risk second graders. *Journal of Learning Disabilities, 40,* 111-120. https://doi.org/10.1177/00222194070400020201

Williams, J. P., Pollini, S., Nubla-Kung, A. M., Snyder, A. E., Garcia, A., Ordynans, J. G., & Atkins, J. G. (2014). An intervention to improve comprehension of cause/effect through expository text structure instruction. *Journal of Educational Psychology, 106,* 1-17. https://doi.org/10.1037/a0033215

Wolman, C. (1991). Sensitivity to causal cohesion in stories by children with mild mental retardation, children with learning disabilities, and children without disabilities. *The Journal of Special Education, 25*, 135-154. https://doi.org/10.1177/002246699102500202

Yeari, M., & van den Broek, P. (2016). A computational modeling of semantic knowledge in reading comprehension: Integrating the landscape model with latent semantic analysis. *Behavior Research Methods, 48,* 880-896. https://doi.org/10.3758/s13428-016-0749-6

Zwaan, R. A., & Rapp, D. N. (2006). Discourse comprehension. In M. Traxler & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics* (2nd ed., pp. 725-764). San Diego, CA: Academic Press. https://doi.org/10.1016/B978-012369374-7/50019-5