Doctoral dissertation

Inferential processes, Updating information and Working Memory in Reading Comprehension of Adults

by

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El mundo habrá acabado de joderse el día en que los hombres viajen en primera clase
y la literatura en el vagón de carga.

The world must be all fucked up, when men travel first class
and literature goes as freight.

Gabriel García Márquez

A Fabiano,

por invitarme a tantas reflexiones.

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1. INTRODUCTION

Dear reader[1], imagine that you have decided to spend a Sunday afternoon reading for pleasure. From the bookshelf at home you take that book of Julio Cortázar that a friend gave you several months ago and you read "End of the game". On opening the cover, the title of the first story inspires you and you begin to read:

> "*He had started reading the novel a few days before. Urgent business made him abandon it for a time; but he returned to its pages while on his way back to the farmland estate. He gradually let himself become interested in the plot, in the characters. That evening, after writing a letter to his representative and discussing a matter of sharecropping, he took up the book again in the tranquility of his study which gazed out upon the park of oak trees. As he lounged in his favorite chair with his back to the door that would have bothered him with the irritating potential for intrusions, he let his left hand stroke the green velvet once then again, and he began to read the final chapters. His memory retained with no effort the names and appearances of the main characters, and so the novelistic illusion came upon him almost immediately… First the woman came in, mistrustful. Then her lover arrived, his face hurt from the whiplash of a branch. Admirably she clotted the blood with her kisses, but her caresses were rejected: he had not come to repeat the rituals of a secret passion protected by a world of dry leaves and furtive paths. The dagger grew warm against his chest, and below beat cowering liberty. A breathy dialog ran through the pages like a stream of serpents, which felt as if it had always been so. Even as these caresses swirled around the lover's body as if trying to hold him and dissuade him, they drew at the same time the abominable shape of another body which had to be destroyed…*"

If you stop for one second to ask yourself, 'who has the dagger in the story and whom does he/she wants to kill?' you would probably infer quite plausibly that it is the woman's lover who has the dagger, and that the two lovers have decided to kill her husband. Nevertheless, if you continue reading:

> "*No longer looking, bound rigidly to the task which was awaiting them, they separated at the door of the cabin. She had to follow the trail that led north. From the opposite trail, he turned for a moment to watch her run with her hair flowing loosely. He then ran in turn, taking shelter beneath the trees and hedges until, in the mallow mist of twilight, he was able to make out the avenue that led to the house. The dogs were not supposed to bark; and they didn't. The majordomo would not be in at this hour; and he wasn't. He climbed the three stairs of the porch and went in. In the blood swishing between his ears rang the words of the woman: first a blue room, then a gallery, then a carpeted staircase. Upstairs, two doors. No one would be in the first room, no one in the second. The door of the living room, and then the dagger in his hand, the*

[1] If you are native Spanish, please find original version of Cortázar's story in Appendix A (p. 191).

light of those large windows, the old recliner with green velvet seat, the head of a man reading a novel." (Cortázar, 1994)

And now, after reading this, who does the lover kill and at which level the story unfolds? Only if the reader has maintained in memory the information described at the beginning of the story, will he/she be able to understand that the husband who the lovers decided to kill is the very same character in the story who reads the novel. The change of perspective from the book that the character reads to the book you read, involves an update of the plane where the story unfolds, and thus forces a reinterpretation of what has been read.

The above text serves to illustrate the complexity of some of the cognitive processes involved in text comprehension, such as the ability to extract information that is not explicitly mentioned, the ability to maintain and retrieve information in memory, as well as the ability to replace an incorrect interpretation with a new one that is more probable. All of these processes are necessary to create a mental representation of the text that is coherent, precise and accurate. Clearly reading comprehension requires a large amount of cognitive resources.

1.1. READING COMPREHENSION PROBLEMS IN ADULTS

The Organisation for Economic Co–operation and Development (OECD) performed the *Programme for the International Assessment of Adult Competencies* (PIAAC), for the first time between 2011 and 2012. The PIAAC evaluated the skills of reading comprehension and mathematics of 157,000 adults between 16 and 65, from 23 countries: most European countries, Australia, Canada, USA and Japan (www.oecd.org/site/piaac/surveyofadultskills.htm). Subsequently, an international report of the PIAAC (October 2013) has shown that Spain has one of the lowest scores in both reading comprehension and mathematics, where the reading comprehension of Spanish adults (252) is well below the European average (271) and the OECD average (273). As consequence of these reading problems, people have difficulties understanding long and digital texts (e.g., patient information leaflet). In fact, a more detailed analysis of some socio–demographic characteristics shows that 1) according to educational level, in some countries such as Japan and the Netherlands high school or vocational education graduates score better on reading comprehension than postgraduates in Spain; and 2) according to age, although elderly people have the worst outcomes, young people aged between 16–24 (263.9) and 25–34 (262.8) years old, still are below the OECD average (279.6 and 284.1 respectively). Taking these data into account, the study of cognitive and neurophysiological processes underlying reading comprehension on adults is particularly relevant and therefore, it will be the focus of the present doctoral dissertation.

1.2. READING COMPREHENSION

The word comprehension derives from Latin; the prefix '*com*' means fully and the verb '*prehendere*' means seize or grasp. Therefore, comprehension is the process by which the meaning of any information is *fully seized*. This cognitive ability to understand the whole meaning of any information is present in essential activities, such as learning, reasoning, problem solving and decision making (McNamara & Magliano, 2009). Moreover, considering that the process to understand words, sentences, and paragraphs entails the development over years of practice, it is reasonable to think that text comprehension serves as an index of general cognition.

1.2.1. Development of language comprehension

From before birth (around the sixth month of pregnancy), the ear of the future child is sufficiently mature to hear sounds like the voice of the mother (Hepper & Shahidullah, 1994). He/she still fails to understand, but has already acquired the basis for acquiring language. After birth, in a first attempt to communicate, the child attends and retains the information that is provided orally (by learning new words, the association of related concepts, etc.) and, in this way, develops oral language comprehension skills (e.g., Sénéchal, LeFevre, Thomas, & Daley, 1998). This learning process continues across one's lifetime and is the main reason for the appearance of the first spoken words. Once the child has started this process of production, he/she is able to communicate with others through the expression of intentions and desires, the rejection of options that do not satisfy him/her, or the simple repetition of what he/she does not understand (e.g., Benedict, 1979). Therefore, the child quickly improves his/her phonological skills, increases vocabulary, establishes complex relationships between ideas, constructs grammatical structures and many other linguistic features that will consolidate his/her knowledge (e.g., Muter, Hulme, Snowling, & Stevenson, 2004). Upon entering kindergarten, the child faces for the first time reading as an educational activity. However, it is not until a couple of years later (first and second grade) when the child has sufficient word reading skills to explore on their own the fantastic world of reading texts (Sénéchal, LeFevre, 2002).

1.2.2. Simple View of Reading

Despite its simplicity, as its name suggests, the Simple View of Reading (Gough & Tunmer, 1986) has been probably the most influential model in the literature of reading comprehension. This basic model distinguishes two necessary components for reading: lexical decoding and linguistic comprehension. *Decoding skill* refers to the ability to read individual words, in a very fast, precise, and silent manner, while *linguistic comprehension* broadly includes the processes that enable understanding by interpreting sentences or discourse. According to Gough and Tunmer (1986) the product of both domains results in reading comprehension (see Figure 1).

Therefore, limited language skills in one of those components can impair reading comprehension, as for example when children misidentify a word (poor lexical decoding), or when they misunderstand a word or fail to parse the syntactic structure of sentences (poor linguistic comprehension). The empirical evidence that supports the Simple View of Reading is extensive and it has demonstrated the importance of the interplay of both decoding and linguistic skills in reading (e.g., Catts, Hogan, & Adlof, 2005; Cutting & Scarborough, 2006; Johnston & Kirby, 2006; Nation, Clarke, Marshall, & Durand, 2004; Savage & Wolforth, 2007; Vellutino, Tunmer, Jaccard, & Chen, 2007).

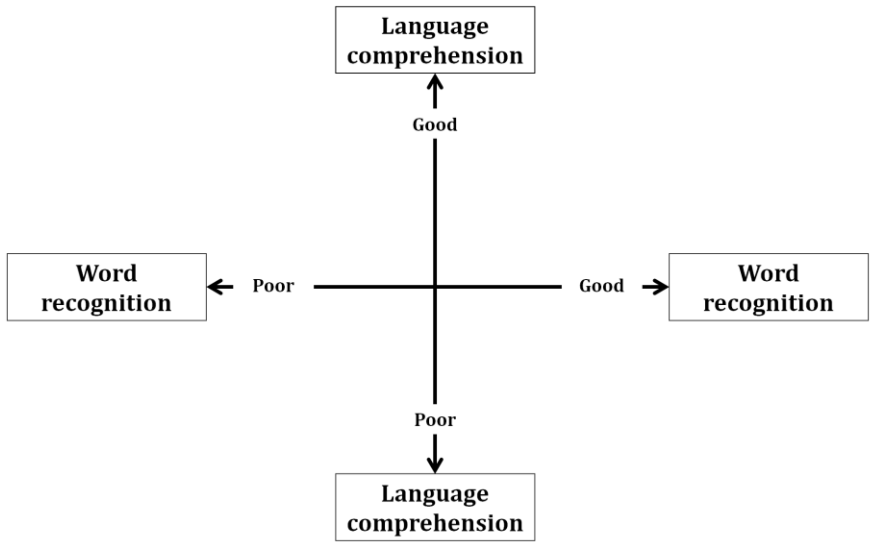

Figure 1. Simple View of Reading (Gough & Tunmer, 1986), in which two continuums are distinguished: one including the processes of decoding or word recognition; and another taking into account the processes of language comprehension. Both continuums interact.

1.2.3. Levels of information representation

The division provided by the Simple View of Reading serves as a general approximation to understand the basic structure of reading, but does not delve into the dynamics of cognitive processes required to achieve good comprehension. These processes are multiple and varied, and their categorization depends on the level of competence demanded by the type of information (Balota, d'Arcais, & Rayner, 1990). Therefore, in general, the levels of information representation go from word representation to the mental representation of the text.

According to Kintsch (1998; see also van Dijk & Kintsch, 1983), four levels of representation can be distinguished: linguistic, semantic, text–base and situation model. The *linguistic* level deals with lexical processes and parsing sentences. Word recognition is essential for successful reading comprehension since words are the simplest units of information. Similarly, the syntactic function that each word plays in a sentence is also crucial for reading since it helps to organize the information by determining the grammatical relations that are established between the components of the sentence (e.g., Kaan & Swaab, 2002). However, despite that both word recognition and syntactic function (linguistic level) are necessary for reading comprehension they are not sufficient conditions to represent the main ideas of a text. The *semantic* level includes the comprehension of word and sentence meaning (microstructure) as well as the ideas derived from the combination of words and sentences (macrostructure). Thus, the semantic representation enables the comprehension of the fundamental ideas of a text, which not necessarily must be connected. The *text–base* level requires an understanding of the information that is explicitly described in the text. To do so, readers connect text information providing coherence to the story. Nevertheless, the text–base representation does not include reader's prior knowledge (e.g., identifying the global theme of the story), so this mental representation of the text is still limited. Finally, the *situational model* level is based on a more comprehensive and detailed representation, in which text information and reader's background knowledge are combined. The situational model itself demands the identification of the most relevant ideas in the text (bottom–up process) and the re–elaboration of these ideas with the prior knowledge of the reader, which influences interpretation (top–down process). However, rather than different and separate mental representations, the text–base and the situation model can be seen as distinct dimensions of the same episodic memory continuum (Graesser & Clark, 1985; Kintsch, 1988; van Dijk & Kintsch, 1983). In addition, it is important to notice that the situation model does not need to be exclusively verbal, since it may contain mental images or even emotional information.

A relevant approach of how reading comprehension operates is the Reading Systems Framework (Perfetti, 1999; see Perfetti & Adlof, 2012; Perfetti & Stafura, 2014). The model provides an integrated view going from the recognition or identification of words to the construction of the situation model. Furthermore, the Reading Systems Framework reflects how high–level processes depend on the effectiveness of low–level processes (see Figure 2). It represents how visual information inputs first at an orthographic system, where the orthographic and phonological units are combined. Then, word identification makes access to the lexicon possible, where morphology, syntax and meaning are assigned to words by means of both reader's linguistic knowledge and reader's general knowledge. Subsequently, by assigning word meaning and the selection of the form, words become part of the comprehension processes. At this point begins a constant interaction between the processes involved in parsing, the text–base and the situation model representations. It is important to note that the situation model also provide the context for word meaning assignment. In addition, of particular interest to the present thesis is the inclusion of an inference making unit that participates in the construction of the text–base representation as well as in the elaboration of the situational model.

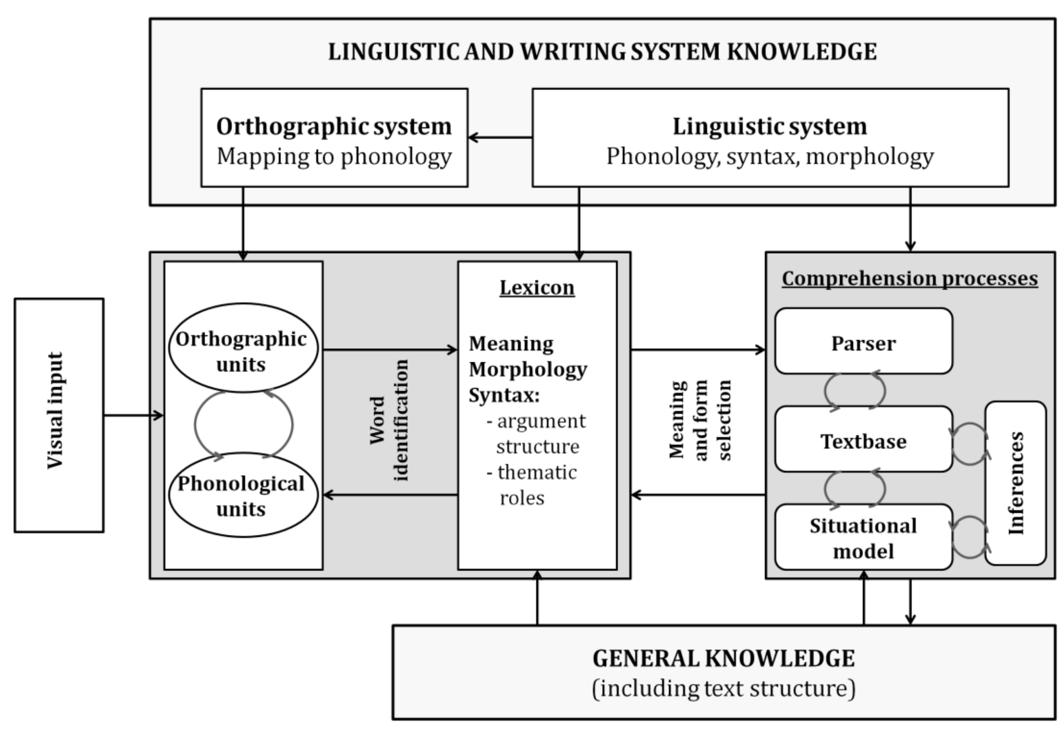

Figure 2. The Reading Systems Framework (adapted from Perfetti, 1999; Perfetti & Adlof, 2012). The model illustrates the division between the different systems or modules of reading (orthographic system and language system, as well as general knowledge), through which the processes involved in reading (e.g., word identification or inferences) are developed.

The Reading Systems Framework includes three assumptions about reading: 1) there are three types of source knowledge: *orthographic*, *linguistic*, and *general*. The general knowledge refers to reader's world knowledge, considering also the knowledge about the text structure (e.g., text genres); 2) the processes of reading (decoding, word identification, assignment of word meaning, parsing, inference making and comprehension monitoring) make use of the three types of knowledge in a *constrained* way (e.g., decoding requires the orthographic knowledge but not the general knowledge), and an *interactive* way (e.g., inference making requires the combination of the ideas presented in sentences and the general knowledge); 3) the processes of reading are set in a cognitive system, which connects perceptual and long–term memory systems through a limited working memory capacity.

The Reading Systems Framework is a very comprehensive model about how reading comprehension is achieved, which has served as a reference in several studies (e.g., Apthorp, Randel, Cherasaro, Clark, McKeown, & Beck, 2012; Sabatini, O'Reilly, & Deane, 2013; Sabatini, O'Reilly, Halderman, & Bruce, 2014). Nevertheless, it is necessary to note that this model is a simplified diagram of reading components: in fluent reading these components operate and interact continuously, at vertiginous speed and with simultaneous execution at different levels. Furthermore, the construction of a situation model relies on further higher–level factors to develop a coherent and integrated mental representation, that are not fully explained by the Reading Systems Framework.

The present thesis is focused on some of the high–level comprehension processes that are involved in the construction of the situation model. More concretely, we refer to inference making, which allows the reader to extract information that is not explicitly described in the text (e.g., Baretta, Tomitch, MacNair, Lim, & Waldie, 2009; Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001; van den Broek, 1989); comprehension monitoring, which helps readers to verify their understanding of what they have read (Baker, 1989; Kinnunen & Vauras, 2010; Vorstius, Radach, Mayer, & Lonigan, 2013; Wagoner, 1983); and the updating of information, which is used to replace outdated information with new information that is more consistent with the context (Carretti, Belacchi, & Cornoldi, 2010; Carretti, Borella, Cornoldi, & De Beni, 2009; O'Brien, Cook, & Guéraud, 2010; Radvansky & Copeland, 2010). These three high–level cognitive processes will be described in subsequent sections (sections 1.3., 1.4., and 1.5., respectively). In addition, since we are also interested to understand whether individual differences in working memory influence the performance of these cognitive processes, we will include a final section (section 1.6.) with empirical evidence connecting high–level processes to working memory capacity.

1.3. INFERENCE MAKING

Inference making is inherent to comprehension. In reading comprehension, inferences are essential to construct a coherent situation model because they provide the necessary connections to extract the implicit ideas of a text. Due to this, it is clear why most of comprehension models make explicit reference to the process of inferences generation (Albrecht & O'Brien, 1993; Gernsbacher, 1990, 1997; Graesser, Singer, & Trabasso, 1994; Kintsch, 1988, 1998; Linderholm, Virtue, Tzeng, & van den Broek, 2004; Magliano, Zwaan, Graesser, 1999; Myers & O'Brien, 1998; Trabasso, van den Broek, & Suh, 1989; van den Broek, Rapp, & Kendeou, 2005; Zwaan & Radvansky, 1998).

1.3.1. General principles

Beyond the multiple taxonomies and materials that have been used to describe inference making (e.g., Graesser, et al., 1994; Zwaan & Radvansky, 1998), several properties can be identified as the 'backbone of inferences':

1. *Functions.* Inference making has three important functions in text and discourse comprehension: coherence, integration and causality. Inferences are required to provide coherence to the mental representation of the text during reading comprehension (e.g., Graesser, et al., 1994; Magliano, et al., 1999; Zwaan & Radvansky, 1998). Text coherence is reached through establishing connections between the current information and both prior parts of the text and/or prior knowledge. In fact, when coherence breaks occur, readers are forced to 'repair' their comprehension with a more plausible alternative, which may demand inference making. According to Gernsbacher (1990), there are at least four sources of coherence that improve the establishment of connections in reading comprehension: *referential* coherence relates to the existing connection between something or someone that is mentioned, and a previous reference of that

thing/person (e.g., '*We got some* <u>*beer*</u> *out of the trunk. The* <u>*beer*</u> *was warm*'); *temporal* coherence refers to the accuracy that is maintained in relation to the time (e.g., '*I arrived at the start line at* <u>*7:45 a.m*</u>*. The marathon was scheduled to begin at* <u>*8:00*</u>*… At* <u>*eight o'clock*</u> *sharp the starter fired his pistol.*'); *locational* coherence provides consistency in relation to the space (e.g., '*Mike and I were standing in the hallway* <u>*near my office*</u>*. We were enthusiastically discussing some new data. In a* <u>*nearby office*</u>*, people had difficulty concentrating.*'); and *causal* coherence explains why something happens or what will happen (e.g., '*Brian* <u>*punched*</u> *George. George* <u>*called the doctor*</u>*.*'). Hence, inference making is critical to construct coherent representations of the text. In addition, text information and background knowledge must be integrated in order to understand the main ideas of a text. Thus, the degree of integration elaborated in the mental representation also depends on inferential connections (e.g., Magliano, et al., 1999; Zwaan, Langston, & Graesser, 1995). Interestingly, the Construction-Integration model (Kintsch, 1988, 1998) has distinguished two phases: the *construction* phase, which brings general activation to both the current text information and the related prior knowledge; and the *integration* phase, which refines the current mental representation 1) activating the more semantically interconnected concepts, and 2) deactivating the more disconnected ideas. Therefore, the process of properly integrating information into the situation model also requires the suppression of irrelevant information. Moreover, several studies have highlighted the importance of inference making in establishing causality (e.g., Millis & Graesser, 1994; Singer, Halldorson, Lear, & Andrusiak, 1992; Walsh & Johnson–Laird, 2009). The relation between causality and inference making goes in both directions: causality facilitates the generation of inferences, and inferences help to establish causal relationships. The Causal Network model of comprehension (Trabasso, et al., 1989) has mainly focused on the role of causal relationships to activate and bind different types of information in a text. Concretely, the model defends four types of causal relationships: 1) *enabling*, in that specific information helps or facilitates the activation of other information (e.g., reading '*Harry worked as a stable lad and this was his first race*' facilitates the idea of 'horse race'); 2) *psychological*, they connect different information on the basis of the mental states of a character (e.g., reading '*David had lost his job and now his wife had left him. Today he drove up to the *clifftops near his home*' it connects the idea of 'suicide'); 3) *motivational*, they establish links taking into account the interests of characters (e.g., reading '*The vampire would die if he did not drink*' suggests that the vampire was motivated to drink 'blood'); and 4) *physical*, they connect information in relation to the external conditions (e.g., reading '*It was raining heavily. Liza had an important meeting and did not want her hair to get ruined*' it suggests that Liza was going to take an 'umbrella'). Thus, according to the model inferences are required to construct a coherent and integrated mental representation that encodes causality.

2. *Type of processing.* There is wide agreement that readers must be involved in effortful and deep reading comprehension in order to generate inferences. Thus, readers with high involvement are more likely to draw inferences (McNamara & Magliano, 2009) than readers with low involvement. In fact, it has been demonstrated that readers with a shallow goal of comprehension may fail to generate causal inferences (e.g., Linderholm, et al., 2004; van den Broek, Virtue, Everson, Tzeng, & Sung, 2002). However, inference making may entail different levels of processing going from low demand to high demand of resources (see e.g., Perfetti, Landi, & Oakhill, 2005). On the one hand, an example of a low demanding inference could be an anaphoric resolution e.g., in the sentences '*Ann predicted that Pam would lose the track race, but she came in first very easily*' the pronoun 'she' is easily mapped into the antecedent 'Pam' instead of 'Ann' (Corbett & Chang, 1983); on the other hand, a high demanding inference could be the generation of a causal relationship between information that is poorly connected e.g., in the sentences '*Joey went to a neighbor's house to play. The next day, Joey's body was covered in bruises*' (Keenan, Baillet, & Brown, 1984). Consequently, inferences may be represented in a continuum of processing depending on the resources that are necessary to generate them.

3. *Direction of processing*. Inferences can be driven by *bottom–up or top–down* processes. Despite the existing disagreement between comprehension models to determine the direction by which comprehension occurs (e.g., Albrech & Myers, 1995; Graesser, et al., 1994; Magliano & Radvansky, 2001; Myers & O'Brien, 1998), both text–driven (bottom–up) and goal–directed (top–down) processes are involved in inference making. For example, when the text primes reader's world

knowledge without difficulty (e.g., '*The monkey received a piece of fruit as treat*'), readers generate automatic inferences associated with bottom–up processes (e.g., idea of '*banana*'). In contrast, when readers do not have sufficient prior knowledge and the text is difficult or unfamiliar (e.g., '*Neutrinos are created as a result of certain types of radioactive decay, or nuclear reactions such as those that take place in the Sun, in nuclear reactors, or when cosmic rays hit atoms*'), they generate more controlled inferences associated with top–down processes, although this does not necessarily demand resource-heavy processing. Therefore, inference making is involved in text comprehension by both bottom–up and top–down processes, the particular direction depending on the characteristics of the text.

4. *Prior knowledge and memory*. Coherence and integration is sometimes achieved by connecting textual information, but in most cases requires activating knowledge not present in the text (prior knowledge). Explaining information that is not explicit or is missing from the text requires that readers trigger inferences that go beyond text information. Accordingly, the importance of inferences in the interaction between text coherence and prior knowledge has been demonstrated. Readers with low prior knowledge achieve better comprehension when the text is highly coherent, whilst readers with high prior knowledge only benefit from their knowledge when the text is low in coherence (e.g., McNamara, Kintsch, Songer, & Kintsch, 1996; Ozuru, Dempsey, & McNamara, 2009). Nevertheless, background knowledge must be available and accessible to the reader in order to elaborate inferences (Perfetti & Adlof, 2012). Similarly, inference making depends on memory processes. Any inference related to text information must be maintained in working memory capacity, and all information that is inferred from prior knowledge required the activation of long–term memory capacity. According to this, the Resonance model proposes that the current text information activated in working memory, reactivates (or resonates) prior parts of the text and/or prior knowledge from long–term memory (e.g., Albrecht & O'Brien, 1993; Myers & O'Brien, 1998; Myers, O'Brien, Albrecht, & Mason, 1994). Additionally, some theoretical proposal suggests the existence of a long–term working memory that helps to keep the relevant prior knowledge active while reading the text (Ericsson,

1995). Then, the mental representation of a text requires inferences by means of memory processes and activation of prior knowledge.

In summary, inference making is involved in the construction of a coherent and integrated situation model of the text, where causal relationships have an important function. Nevertheless, according to their activation, inferences can be seen as a continuum of processing going from low demand to high demand of resources. In addition, the direction of inferential processing depends on the specific information being either text–driven (bottom–up) or goal–directed (top–down). Finally, in order to provide coherence inferences require the activation of prior knowledge, and are supported by several memory processes that take place in working memory. We will now describe a well–known categorization of two types of inferences that are necessary to establish text coherence.

1.3.2. Text–based and knowledge–based inferences

The literature of inference making has distinguished one broad category referring to inferences that help to maintain coherence based in text information. In this sense, text–based inferences are generated when the current information is connected to prior information during text reading (e.g., '*The tourist took the picture of the church. The camera was the best he had ever owned*' indicates that the tourist used a camera; Singer, 1980). In fact, most models of comprehension recognise the role of the text–connecting inferences. For example, the Causal Network model (Trabasso, et al., 1989) has emphasised the role of text–based inferences in relation to the causal, spatial and temporal situational continuities.

Text–based inferences are also known as *bridging* inferences, illustrating the connection or bridge that supports the inference (Haviland & Clark, 1974). According to Singer (1993), the connections or bridge may occur in two ways. On one hand, the bridging inference may verify the relationship between two (or more) sentences, elements or ideas; for example, the existing relationship between an event (e.g., murder) and an argument (e.g., victim) can be connected by their thematic role (e.g., the murderer will try to kill the victim, and not the reverse). On the other hand, the bridging inference may entail the generation of a new idea, since that idea can be necessary to properly generate the connection; for example, in '*The spy quickly threw his report in the fire. The ashes floated up the chimney*' the reader must infer that '*The report burned to ashes*' (Singer & Ferreira, 1983). It is important to notice that this new idea requires retrieving some prior knowledge from long–term memory. Thus, although bridging inferences are mainly based on text information, some may draw on world knowledge. Finally, taking into account that text–based inferences are generated to provide text coherence, a fail to trigger a bridging inference during reading may cause a disruption of comprehension (Haviland & Clark, 1974; Kintsch & van Dijk, 1978; Singer, 1980).

Furthermore, when the connection between the current information and prior information is very close in proximity (e.g., one or two immediate preceding sentences), readers generate a *local* inference (e.g., Garrod & Sanford, 1990; Kintsch & van Dijk, 1978; van den Broek, Lorch, Linderholm, & Gustafson, 2001; Virtue & van den Broek, 2005); however, when the connection is established with a more distant text information (e.g., one or two preceding paragraphs), then readers are generating a *global* inference (e.g., Graesser, Wiemer–Hastings, & Wiemer–Hastings, 2001). In this sense, there is much empirical evidence with on–line measures demonstrating that reading time varies systematically with the semantic distance between the current sentence and the precedent ideas to which it must be bridged (Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Keenan, et al., 1984; Myers, Shinjo, & Duffy, 1987; see McKoon & Ratcliff, 1980, for a critique). These results signal the on–line course of bridging inferences during reading (Singer, 1993). Additionally, another way to generate global inferences is to extract the overall gist or themes of the text (e.g., the main topic of the story). Thus, global coherence inferences can be maintained by connecting current information with prior text information or prior knowledge (Albrecht & O'Brien, 1993; Graesser et al., 1994; McKoon & Ratcliff, 1992).

Complementary to text–based inferences, the literature on inference making includes another broad category referring to inferences that integrate text information with background knowledge. In this sense, knowledge–based inferences are generated when current text information activates appropriate prior knowledge. Despite that both text and knowledge–based inferences are relevant to the construction of a situation model (McNamara & Magliano, 2009) knowledge–based inferences have been considered only in few models of comprehension. In relation to this, some researchers have highlighted the role of knowledge–based inferences by defining reading comprehension as an effortful constructive process (e.g., Graesser, et al., 1994).

Two types of knowledge–based inferences have been distinguished: coherence and elaborative inferences (McKoon & Ratcliff, 1980). *Coherence* (knowledge–based) inferences connect current text information with relevant background knowledge in order to understand essential ideas of a text (e.g., '*The doctor became very nervous as he watched the patient's pupils. He had seen this kind of problem only once or twice before*' it suggests the idea of 'sick'; Till, Mross, & Kintsch, 1988). In contrast, *elaborative* inferences embellish text representation with prior knowledge but they are not strictly necessary for coherence (e.g., '*The tourist took the picture of the church. The scene was more beautiful than he remembered.*' it requires to elaborate the idea that '*The tourist used a camera*'; Singer, 1980). By the 1980s and early 1990s, several studies conducted on elaborative inferences concluded that these elaborations are vaguely encoded into the situation model (e.g., McKoon & Ratcliff, 1986; McKoon & Ratcliff, 1992; Potts, Keenan, & Golding, 1988; Singer, 1980; Singer & Ferreira, 1983). However, it has been demonstrated that highly constrained semantic contexts facilitate the encoding of elaborative inferences (e.g., '*They carved the bird for Thanksgiving*' easily suggests the idea of 'turkey'; Anderson, Pichert, Goetz, Schallert, Stevens, & Trollip, 1976; Whitney, 1986). According to this, the *minimalist hypothesis* (McKoon & Ratcliff, 1980) claimed that inferences are only automatically encoded during reading when 1) they require information that is quickly and easily available in memory, or 2) they are necessary to provide coherence by text information or prior knowledge.

Beyond the previous distinction, McKoon and Ratcliff's minimal position has been interpreted as proposing that readers encode knowledge–based inferences only when they connect information that enables coherence of the text–based representation. In fact, knowledge–based inferences are bridging inferences when they required integrating several parts of text information (e.g., '*He cut the bread. The knife was blunt.*' it demands to connect that '*The knife was the tool used to cut the bread*'). Therefore, as with text–based inferences, knowledge–based inferences are necessary to the maintenance of local and global coherence throughout a text (e.g., Cain & Oakhill, 1999; Cain et al., 2001; Graesser & Clark, 1985; Graesser et al., 1994; McKoon & Ratcliff, 1992; McNamara et al., 1996). In relation to this, several researchers have investigated whether knowledge–based inferences are interconnected to text information (Cain & Oakhill, 2006; Oakhill, 1982; O'Reilly & McNamara, 2007; Rapp, van den Broek, McCaster, Kendeou, & Espin, 2007). Additionally, other categorisations of knowledge–based inferences have been proposed (e.g., Trabasso & Magliano, 1996) distinguishing for example between explanatory or explicative inferences (e.g., Beeman, Browden, Gernsbacher, 2000; Narvaez, van den Broek, & Ruiz, 1999); associative inferences (e.g., McKoon & Ratcliff, 1992; Oakhill, 1983); and predictive inferences (e.g., Calvo, Castillo, & Schmalhoffer, 2006; Peracchi & O'Brien, 2004).

Therefore, text–based inferences connect the current text information with prior sentences, while knowledge–based inferences connect the current information with prior knowledge (see Figure 3). Moreover, although bridging inferences are commonly described as text–based inferences, they can be also associated to knowledge–based inferences if they required the activation of prior knowledge. More importantly, both types of inferences are necessary to provide coherence to the situation model.

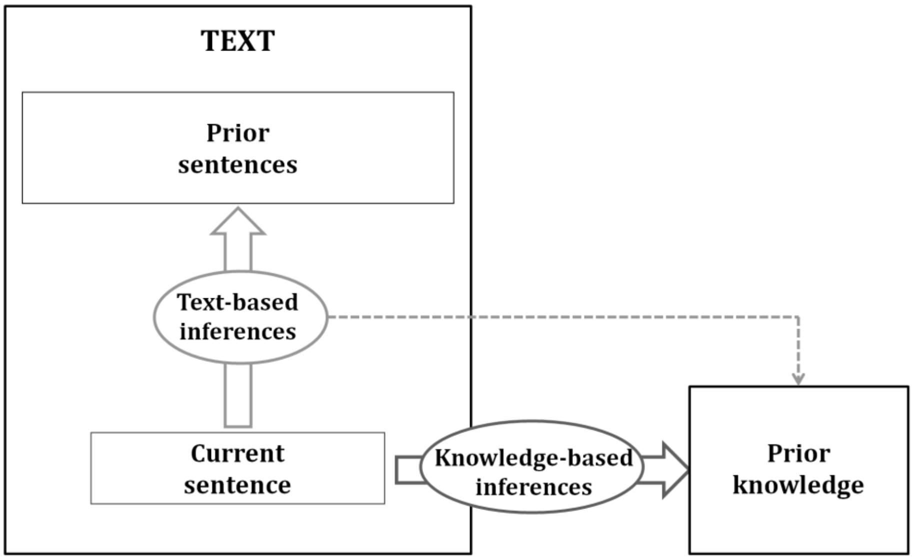

Figure 3. Simplified diagram (adapted from McNamara & Magliano, 2009) representing text–based inferences, which are 'up' to prior sentences in the text, and knowledge–based inferences, which are 'out' to prior knowledge. In addition, we have included a possible relationship between text–based inferences and prior knowledge (dotted arrow), to illustrate how sometimes bridging inferences connect text information by the retrieval of world knowledge.

1.3.3. Causal inferences

As it has been indicated with the general principle of causality, causal inferences play an especially central role in text cohesion (Black & Bower, 1980; Graesser, 1981; Graesser & Clark, 1985). Although some researchers have classified causal inferences as a text–based (e.g., Trabasso, et al., 1989), we also consider here the causal inferences that are supported by prior knowledge (knowledge–based inferences).

Causal inferences make possible the establishment of connections between an effect and its cause. Rather than single elements, causes are disjunction or conjunctions of sufficient conditions, so the representation of causal relationships is more related to networks than linear orders (Mackie, 1980). Therefore, under certain story circumstances readers look for and create the necessary and sufficient information to map the causal relationships into their situation model. For example, given an event (e.g., '*the baby stopped crying after he saw the feeding bottle on his mother's hand*') readers generate causal inferences to explain a causal antecedent (e.g., '*the baby cried because he was hungry*') or anticipate a causal consequence (e.g., '*the baby stopped crying because he was expecting to eat*'). These causal antecedent and consequence inferences connect text information referring to events, states, or actions of characters with reader's prior knowledge, usually on the basis of physical or psychological causes (e.g., Millis & Graesser, 1994; Singer, et al., 1992). In relation to this, an interesting approach is the Constructionist view (Graesser, et al., 1994). The Constructionist theory assumes that readers generate explanations to connect and construct the relevant information of the story, which also helps to reach text coherence (e.g., Magliano, Trabasso, & Graesser, 1999). Moreover, this explanatory coherence is achieved by the generation of knowledge–based inferences such as the causal antecedents that are drawn when specific information appears in the focal sentence activating the appropriate cognitive processes that generate the inference (see Graesser, et al., 1994).

Empirical evidence of causal inferences has shown that readers are faster and/or more accurate at answering comprehension questions when they have generated explanatory coherence (Graesser, Millis, & Zwaan, 1997; Magliano, Baggett, Johnson, & Graesser, 1993; Singer, 1995). In fact, explanations are related to causal inference (Johnson–Laird, Girotto, & Legrenzi, 2004; Sloman, 2005, 2009; Byrne, 2005; Walsh & Johnson–Laird, 2009). For example, Kuperberg, Paczynski, and Ditman (2010) used event-related potentials to evaluate sentences that varied in their causal coherence. They presented three conditions: 1) highly related (e.g., '*Jill had very fair skin. She forgot to put sunscreen on. She had* <u>*sunburn*</u> *on Monday.*' where readers must infer that sunburn results from forgetting to put on sunscreen, particularly if one has fair skin); 2) intermediately related (e.g., '*Jill had very fair skin. She usually remembered to wear sunscreen. She had* <u>*sunburn*</u> *on Monday.*' where readers must make the above inference but must also infer that although Jill usually puts on sunscreen, this time she forgot); and causally unrelated (e.g., '*Jill's skin always tanned well. She always put on sunscreen. She had* <u>*sunburn*</u> *on Monday.*' where there was no clear inference that could be made since the second sentence established that it was highly unlikely that Jill would not put on sunscreen and the first sentence stated that even had she forgotten, she would not be likely to sunburn). Kuperberg, et al., (2010) found that the critical words (those that are underlined in the example above) evoked a larger N400 in the causal unrelated sentences than in both highly causally related and intermediately related sentences. In relation to this, the researchers concluded that both simple and complex causal inferences can influence the earliest stages of semantically processing an incoming word, and that causal coherence at the situation level may influence discourse comprehension by progressing word–by–word. Nevertheless, the benefit of causal consequences is still unclear, since the evidence has produced inconsistent results (Fincher–Kiefer, 1993; Graesser et al., 1997; Graesser & Kreuz, 1993; Lombrozo & Carey, 2006; Magliano et al., 1993). For example, Fincher–Kiefer (1993) investigated the role of predictive inferences in the construction of the mental representation and found that predictions were not encoded into reader's propositional representation during reading, but that they were available at a more abstract level of representation (situation model). Finally, it has been demonstrated that the activation of explanations, which require to connect the current information with a prior referent on the text (causal antecedent) to understand 'why' something occurs, and predictions, which demand to connect the current information with a possible future outcome (causal consequence) to understand what is going to happen, depends on the causal constraints of text information (e.g., Linderholm, 2002; Virtue, van den Broek, & Linderholm, 2006). That is, explanations and predictions are more facilitated when the text strongly suggests causal connections.

To conclude, we have seen that inference making is a fundamental process in the construction of the situation model, essentially because it provides coherence and integration of text information. This can be achieved by connecting several sentences on the text (text–based inferences), or by connecting text information with prior knowledge (knowledge–based inferences). Moreover, causal inferences are very important to generate semantic coherence.

1.4. COMPRENEHENSION MONITORING

Comprehension monitoring in reading refers to the metacognitive awareness that readers have about what they read (see Baker, 2002; Brown, 1980;

Ruffman, 1996; Wagoner, 1983). Good readers monitor the current text information in relation to previous parts of the text and prior knowledge. According to this, several authors have claimed that comprehenders continuously monitor their mental representation along the dimensions of time, space, causality, motivation or intention, and agents (Magliano, et al., 1999; Rinck & Weber, 2003; Therriault & Rinck, 2007; Zwaan & Radvansky, 1998).

Researchers studying comprehension monitoring have commonly used the *error detection* or *contradiction paradigm* (see e.g., Markman, 1979). In this paradigm, prior introductory information explaining a specific character's practice or goal (e.g., a girl being vegetarian) is followed by a consistent (e.g., she orders vegetables) or inconsistent (e.g., she orders meat) action (O'Brien, Rizzella, Albrecht, & Halleran, 1998). A typical time cost effect is found in the inconsistent compared to the consistent sentence (e.g., Cain, Oakhill, & Bryant, 2004; Magliano, Miller, & Zwaan, 2001; Nilsen, Graham, Shannon, & Chambers, 2008; O'Brien, et al., 1998; Rinck & Weber, 2003; Rich & Taylor, 2000). The assumption underlying the paradigm is that these errors or inconsistencies disrupt comprehension, and so the reader that notice this disruption should manifest an increase on processing time reading the inconsistent information.

Two phases have been distinguished in comprehension monitoring: evaluation and regulation (Baker, 1985). The *evaluation* phase specifically refers to the identification or detection of inconsistencies such as lexical ambiguities, grammatical errors, unknown words, semantic confusion, violation of common knowledge, or ambiguous information (Kinnunen & Vauras, 2010) during reading. Some of the empirical evidence for inconsistency detection has been found with grammatical inconsistencies (e.g., Barber & Carreiras, 2005; Zabrucky & Moore, 1999), semantic inconsistencies (e.g., Zhou, Jiang, Ye, Zhang, Lou, & Zhan, 2010), and more relevant for the present work, inconsistencies in text coherence (e.g., Huitema, Dopkins, Klin, & Myers, 1993; O'Brien, et al., 1998; Vauras, Kinnunen, Salonen, & Lehtinen, 2008). The *regulation* phase is related to the repair processes that are necessary to introduce the new information into the memory representation. According to Hacker (1998), *self–regulating reading* is the comprehenders' ability to self–questioning (evaluation) and updating (e.g., revising or repairing inconsistent information) their situation model. Therefore, we will refer to the regulating phase as the updating information process (see section 1.5). Empirical evidence has shown that active self–regulation leads to more effective inference making and more correct answers in inferential comprehension questions (McNamara & Scott, 2001; Goldman & Durán, 1988).

Studies on the development of monitoring skills have demonstrated that the more mature (older) the child is, the more probable is that he/she properly monitors comprehension (e.g., Baker, 1984; Hacker, 1997; Kolić–Vehovec & Bajšanski, 2007; Nilsen, et al., 2008). Nonetheless, adults may also fail to detect inconsistencies in discourse comprehension (e.g., Dunlosky, Rawson, & Middleton, 2005; Epstein, Glenberg, & Bradley, 1984; Glenberg, Wilkinson, & Epstein, 1982), and tend to overestimate their understanding of the text, which has been called the '*illusion of knowing*' (Glenberg et al., 1982). Furthermore, it has been found that more skilled readers (e.g., good comprehenders) are better than less skilled readers in monitoring their comprehension (see Wagoner, 1983, for a review). The failures of comprehension monitoring in adults have been associated with less efficiency in constructing a coherent mental representation that integrates text information (Zwaan & Radvansky, 1998); a poor ability to discriminate when they have comprehended accurately from when they have not (Hosseini & Ferrell, 1982); or a shallow standard for coherence, that means a superficial reader's involvement (e.g., Schommer & Surber, 1986).

Failures in comprehension monitoring do not only come from the evaluation phase, but more importantly they come from the more complex process of updating information. In the next section we will review the literature on updating and the possible failures associated to this process.

1.5. UPDATING INFORMATION

Updating information is the cognitive ability whereby new information is incorporated into memory representation. As it has been previously suggested, the most studied way of updating takes place when an inconsistency between the incoming information and the current mental representation is detected by the reader. Therefore, updating is considered an essential repair process, which is included in the regulation phase of comprehension monitoring (Hacker, 1998).

Three general types of updating processes have been distinguished (Radvansky & Copeland, 2001). First, the simple inclusion of new information (e.g., '*Once there was a Czar who had three lovely daughters. One day the three daughters went walking in the woods… A* <u>*dragon*</u> *kidnapped the three daughters… Three* <u>*heroes*</u> *heard their cries and set off to rescue the maidens...*') into the mental representation (Zwaan, et al., 1995); second, changes on the structural relations of the already activated information due to the modification or alteration of the current entities such as situations, goals, or actions (e.g., '*One day Betty found that her mother's birthday was coming soon… She went to the department store… everything was* <u>*too expensive*</u>*… Several days later, Betty saw her friend knitting…* <u>*She decided to knit a sweater*</u>*… Finally, Betty finished a beautiful sweater… Her mother was excited when she saw the present.*'; Lutz & Radvansky 1997); and third, removal of information from the situation model when prior information is no longer relevant (e.g., '*Warren spent the afternoon shopping at the store. He* <u>*set down*</u> *his* <u>*bag*</u> *and went over to look at some scarves. He had been shopping all day. He thought it was getting too heavy to carry.*'; Glenberg, Meyer, & Linden, 1987).

More recently, Rapp and Kendeou (2007) have defined updating as a broader category of processes entailing encoding and/or adding new information, as well as changing the current mental representation. This definition of updating encompasses several cognitive functions such as the correction of misinformation in memory (e.g., Johnson & Seifert, 1998, 1999); the reactivation of prior text information during reading (e.g., Guéraud, Harmon, & Peracchi, 2005; O'Brien, et al., 2010; O'Brien et al., 1998); and the evaluation of new information against the current discourse model (e.g., Albrecht & O'Brien, 1993; Zwaan & Madden, 2004). Concretely, the *revision* process is a specific type of updating which demands the activation of the information that has been read, the evaluation of possible incompatible information and the substitution of the outdated information with the new one. For example, Rapp and Kendeou (2007) presented an introduction (e.g., '*Albert was listening to the radio. He had finished getting ready to meet his* *friends at the movies… He pulled a sweater over his head. Then he began to look for his shoes.*'), followed by two possible refutation contexts[2]: 1) a simple refutation context (e.g., '*They were buried under old candy wrappers, crumpled magazines, and some dirty laundry. Albert cared about the condition of his room, even though it currently wasn't up to par.*'); and 2) a refutation with explanation context (e.g., '*They were buried under old candy wrappers, crumpled magazines, and some dirty laundry. Albert cared about the condition of his room, but had only moved into the apartment yesterday.*'). Then, after one of these two refutation contexts, a critical situation was presented (e.g., '*Albert had to take the bus to go to the movies. He bought a newspaper to read during the ride to the theatre. Albert had finished leafing through the paper when his stop was announced. Albert put the newspaper on the seat next to him. As he waited for the bus to stop, he noticed a sign asking riders not to leave garbage on the bus.*'), which caused two possible outcomes: a trait–consistent outcome (e.g., '*Albert ignored the sign and got off the bus.*'); or a trait–inconsistent (e.g., '*Albert picked up the newspaper to throw away later.*'). The authors found that in absence of instructions to judge the appropriateness of outcomes (Experiment 2), readers took longer to read the trait–inconsistent compared to the trait–consistent outcome only when the simple refutation context was presented, but not when the refutation with explanation context had appeared. Therefore, it was interpreted that readers were able to revise their mental representation (trait–based expectation) only when the refutation provided a causal explanation, and they were not able to do so when there was a simple refutation.

Consistent with this, a distinction between the processes of updating and outdating information has been proposed (Kendeou, Smith, & O'Brien, 2013). *Updating* refers to the encoding and integration of the incoming information into the reader's mental representation of the text, giving coherence to the situation model. The information that is updated remains active until new information discredits it. *Outdating* appears every time that the incoming information forces the replacement of prior information, which is no longer true or relevant. In this way, the information that is outdated decays, being deactivated from the current

[2] In the original study, there were two other contexts (trait and control) that helped to interpret results (see Rapp & Kendeou, 2007).

memory representation and thus, losing accessibility (Zwaan & Radvansky, 1998). In this sense, there is empirical evidence showing that readers are able to successfully update their situation model (e.g., de Vega, 1995; de Vega, León, & Díaz, 1996; Morrow, Bower, & Greenspan, 1989; Rapp & Kendeou, 2007; Rapp & Taylor, 2004). However, there is also appreciable evidence demonstrating that although the new information can be updated, the outdated information is sometimes maintained, disrupting comprehension (e.g., Guéraud, et al., 2005; Hakala & O'Brien, 1995; Johnson & Seifert, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien, et al., 2010; O'Brien, et al., 1998; Rapp & Kendeou, 2007, 2009; van Oostendorp & Bonebakker, 1999).

As mentioned, readers do not automatically update or revise their situation model to include incompatible information into the current memory representation (van Oostendorp & Bonebakker, 1999). This is a well established assumption in most models of reading comprehension (e.g., Gerrig & McKoon, 1998; Graesser, et al., 1994; Kintsch & van Dijk, 1978; Magliano, et al., 1999; McNamara & Magliano, 2009; O'Brien & Myers, 1999; Zwaan, Magliano, & Graesser, 1995). Thus, readers often hold inaccurate and sometimes even contradictory mental representations.

Several factors have been identified to influence the use of no longer relevant information. For example, Van Oostendorp (1996) found two possible factors: 1) the strength of the original situation model, which if strong may facilitate the processing of the incoming information and thus, the understanding of which prior information must be changed (or make it more difficult if week due to less availability of information); 2) the relevance of information, where it has been observed that, in contrast to Van Oostendorp's expectation, low–relevance information is updated more easily than high–relevance information. Two interpretations have been proposed to explain this result. On the one hand, readers may have problems in the *rejection* process and therefore, they could deliberately refuse to make changes in the information that is part of the core mental representation. On the other hand, if readers have a shallow or *sloppy encoding*, the new contradictory information might also be superficially encoded and they might erroneously think that the new information has been already activated. The later interpretation is especially true when the prior information is highly–relevant, since the representation in memory is strengthened causing a wrong impression of familiarity (see van Oostendorp, Otero, & Campanario, 2002). Interestingly, a more recent proposal is that readers elaborate explanations to resolve inconsistencies and that these explanations may reduce the detection of incompatible information (Khemlani & Johnson–Laird, 2012).

To summarise, together with inference making the metacognitive process of comprehension monitoring is crucial to construct a coherent and integrated situation model. The contradiction paradigm has allowed to distinguish between the detection of an inconsistency (evaluation phase) and the repair of that inconsistency (regulation phase). According to the later, an important way to repair information is the updating process because makes possible the replacement of outdated information with new one. However, much empirical evidence has shown that readers frequently fail to update their mental representation because they have difficulty discarding the outdated information.

1.6. WORKING MEMORY CAPACITY

Working memory is the capacity to actively represent, maintain and manipulate information in mind. In addition, it has an important role in the retrieval of knowledge represented in long–term memory. Therefore, taking into account that all these memory processes are necessary in the construction of the situation model, it is understandable that most models of comprehension recognise the role of working memory capacity in reading comprehension (e.g., Gernsbacher, 1997; Graesser, et al., 1994; Kintsch, 1998; Magliano, et al., 1999; Myers, et al., 1994; Trabasso, et al., 1989; van den Broek, et al., 2005).

1.6.1. The Multicomponent Working Memory model

The most influential approach to working memory has been the Multicomponent model (Baddeley & Hitch, 1974; Baddeley, 2000). This model was proposed as an alternative to the unitary short–term memory models and defends that working memory is a complex system that included distinct interconnected components that are responsible for the temporary storage and the manipulation of information needed in the performance of complex cognitive tasks such as learning, reasoning and comprehension.

The model proposes the existence of three main components: phonological loop, visuospatial sketchpad, and central executive (see Figure 4). The *phonological loop* is responsible for the processing of verbal information (linguistic material), comprising a passive phonological store and an articulatory rehearsal process. The *visuospatial sketchpad* handles the processing of visual and spatial information, and plays an essential role in the generation and manipulation of mental images. Both the phonological loop and the visuospatial sketchpad components are connected directly to the *central executive*, which is responsible for the supervision, control and coordination of the flow of information (Baddeley & Logie, 1999). The central executive component is involved in the allocation of attention (Baddeley, 1986, 1992). Subsequently, a fourth component called *episodic buffer* was added (Baddeley, 2000), which allows a temporary interface between the phonological loop and visuospatial sketchpad and long–term memory, and is also control by the central executive component.

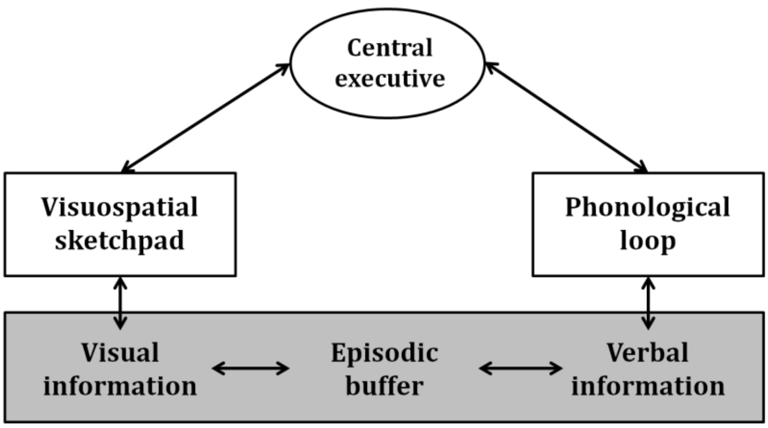

Figure 4. The Multicomponent Working Memory model (adapted from Baddeley, 2000). The white areas represent the slaves systems of temporary storage (visuospatial sketchpad and phonological loop) and the attentional system of control (central executive), while the shaded areas refer to the cognitive systems that maintain and process visual and verbal information as well as retrieve long–term knowledge (episodic buffer).

1.6.2. Working memory and reading comprehension

By the 1980s, several studies had been conducted that showed that working memory capacity predicted individual differences in reading performance (e.g., Just & Carpenter, 1980; Kintsch & van Dijk, 1978; Perfetti & Goldman, 1976). For example, Daneman and Carpenter (1980) devised a task called '*reading span*' which included both storage and processing of information. The authors predicted that although good and poor readers might not differ in short–term memory, they would differ in both the storage functions and the processing functions of working memory. The reading span task in particular correlated with measures of fact retrieval and pronominal reference, confirming that readers with poor reading span were poor in reading comprehension. Furthermore, subsequent research has corroborated the relationship between reading span and many other abilities such as general performance in reading comprehension (Baddeley, Logic, Nimmo–Smith, & Brereton, 1985; Masson & Miller, 1983); the resolution of apparent inconsistencies in "garden path" passages (Daneman & Carpenter, 1983); the integration of information from different parts of a passage (Masson & Miller, 1983); and learning the meaning of a novel word from its context (Daneman & Green, 1986). This was taken as evidence that the reading span task is a measure of working memory and thus, working memory capacity is associated with reading comprehension.

The fact that a low score on the reading span task reflects a reduced processing capacity to deal with the extra processing demands of information suggests that working memory capacity is limited. Additionally, readers with larger working memory capacity has been shown to be better at retaining and processing information during reading as well as at achieving better semantic integration of text representation. In relation to this, Just and Carpenter (1992) developed a theory by which working memory is explained as a limited capacity system for language comprehension. Because this limited capacity, the theory states that in text comprehension readers deactivate prior segments of the text to allow the activation of current text information. In this way, the information that is deactivated during reading loses representation in working memory and becomes less accessible. In relation to this, high–capacity readers have a larger budget of activation and therefore they are more effective storing and processing larger amount of (and more complex) information than readers with low–capacity working memory. In this sense, the reading span task is conceptualised as a measure of the budget allocation, which justifies the relationship between individual differences in reading span and in reading comprehension.

Since, there is wide evidence of the relation between comprehension and working memory, more recent studies have tried to clarify which high–level processes of reading comprehension are influenced by working memory capacity. According to this, studies with children have clearly demonstrated a relationship between working memory and several high–level comprehension skills such as inference making (e.g., Cain, et al., 2001); and comprehension monitoring (e.g., Oakhill, Hartt, & Samols, 2005). Nonetheless, although the research with adults has also shown working memory differences associated to inference making (e.g., Daneman & Green, 1986; St. George, Mannes, & Hoffman, 1997), the involvement of this capacity in comprehension monitoring is less conclusive. For example, De Beni, Borella, and Carretti (2007) studied working memory capacity and metacomprehension components in three types of adults: young (18–30 years), young–old (65–74 years), and old–old (75–85 years). The authors found that although both the young–old and old–old performed poorly comprehending expository texts (which are usually more demanding), only the old–old group performed poorly when comprehending narrative texts, and this poorer performance was associated to differences in working memory capacity and in self–monitoring metacomprehension. Therefore, normal young adults differently to children and older adults do not seem to have difficulties detecting inconsistencies during text reading. In addition, these results highlight the idea that working memory and comprehension monitoring are particularly important for narrative texts.

In contrast, some studies have found a relationship between working memory differences in the updating information process and reading comprehension for both children and adults (e.g., Carretti, Cornoldi, De Beni, & Romanò, 2005; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001). In general these studies show that readers with poor comprehension are also poor at updating information maintained in working memory. This result is important because it suggests the existence of working memory differences in the ability to update information during text comprehension. However, these studies have only evaluated the updating of the contents of working memory by a *memory updating task* (e.g., requiring the recall of the smaller objects after listening a list of words), rather than how readers update information during the construction of a situation model (text comprehension). In addition, considering that the memory updating task is defined as a measure of the central executive component of working memory (Morris & Jones, 1990), it is still unclear whether the relationship of updating information in reading comprehension is specifically restricted to the verbal domain of working memory (without influence of the visuospatial domain) rather than to the central executive component.

1.6.2.1. Inhibitory processes: updating, working memory and comprehension

A relevant approach in the field of individual differences in comprehension has been the Structure–Building model (Gernsbacher, 1990, 1997). This model proposes that when readers find information that is associated with their current representation they *enhance* its activation and include this information in their situation model. On the contrary, when readers detect information that is incompatible with their memory representation they attempt to *suppress* the no longer relevant information. Nevertheless, if readers do not have sufficient skills to suppress the irrelevant information, they may form new substructures constructed out of the main mental representation, which reduces the accessibility of information in memory (e.g., Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990). In relation to this, it has been proposed that readers with poor performance in working memory are also poor in reading comprehension because they have a deficient suppression or inhibitory control over the contents of working memory. In this sense, especially when the task demands are high (e.g., detection of inconsistent information with the current situation model) a deficit in inhibitory control allows more irrelevant information to enter working memory complicating the access and retrieval of relevant information.

Empirical evidence of deficient inhibitory control associated with poor reading comprehension have been found in several paradigms such as the suppression of irrelevant meanings of ambiguous words (Barnes, Faulkner, Wilkinson, & Dennis, 2004; Gernsbacher & Faust, 1991); the suppression of intrusive words (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998); as well as the suppression of proactive interference, where prior encoded information must be inhibited (e.g., Pimperton & Nation, 2010). Interestingly, in a classic study Gernsbacher and Faust (1991, Experiment 4) presented sentences where the last word was ambiguous and the verb in the sentence was biased toward one meaning of the ambiguous word (e.g., '*He dug with the spade.*') and control sentences allowing both meanings (e.g., '*He picked up the spade.*'). Subsequently, readers had to verify if a test word (e.g., '*garden*') fitted the meaning of the sentence they just read. The authors found that although the more skilled comprehenders answered faster than the less skilled comprehenders, the less skilled comprehenders benefitted from the predictable context (facilitation effect) even more than the more skilled comprehenders. These results discarded the hypothesis of a deficit in the enhancement mechanism, that is, less skilled readers are able to appreciate what is contextually appropriate. In contrast, the authors concluded that less skilled readers are less efficient at rejecting inappropriate information because they have deficits in the suppression mechanism (see also Gernsbacher & Fault, 1991, Experiments 1, 2, 3 and 5). According to Cain (2006), one possibility is that the deficit in inhibitory processes affects the regulation of the contents of working memory, deteriorating performance on specific measures of working memory and also reading comprehension in general. Therefore, these findings suggest that readers may fail to update their situation model because they have problems suppressing or inhibiting the outdated information.

To conclude, working memory capacity is crucial to appropriately represent the situation model because it makes possible to actively maintain and process text information as well as to retrieve prior knowledge from long–term memory. The Multicomponent model (Baddeley, 2000) has proposed the existence of several components that may underlie reading comprehension capacity. In fact, there is a strong relationship between reading comprehension and span measures of working memory such as the reading span task. Furthermore, the influence of working memory has been clearly demonstrated in the processes of inference making and updating information, with less conclusive results regarding the comprehension monitoring process. Importantly, the Structure–Building model (Gernsbacher, 1990, 1997) has demonstrated that less skilled readers have problems suppressing no longer relevant information in working memory. This suggests that readers with low working memory could have problems updating their situation model. After emphasising the importance of high–level cognitive processes in the construction of the situation model and reviewing critical empirical evidence of how working memory relates to these comprehension processes, we will now proceed to account for the reasons that motivate the experimental studies of the present thesis.

2. OVERVIEW OF THE RESEARCH

(RESUMEN DE LA INVESTIGACIÓN EN PÁGINA 47)

In contrast to word or sentence processing, text comprehension is a very complex ability that entails to construct a mental representation containing both text information and reader's prior knowledge. This mental representation is known as a situation model (van Dijk & Kintsch, 1983) and it is the starting point of the present work. Moreover, as we have already mentioned, the construction of a coherent and integrated situation model requires the involvement of high–level cognitive processes as well as different memory processes. In this thesis we will focus on how these high–level processes contribute to comprehension of narrative texts. We will concentrate on narrative texts since previous research has shown that narratives have several properties that make them advantageous over expository texts for our research purposes. For example, the content of narratives is often more familiar therefore benefiting memory (Graesser, Hauft–Smith, Cohen, & Pyles, 1980; Kintsch & Young, 1984; Luszcz, 1993; Zabrucky & Moore, 1999), and even when the familiarity is controlled, narratives are easier to comprehend and recall than expository texts (Graesser, Hauft–Smith, Cohen, & Pyles, 1980; Graesser & Riha, 1984). In addition, since narratives are commonly full of scenes, objects and characters playing different roles, intentions and goals (e.g., Graeser, et al., 1994; Radvansky & Dijkstra, 2007) they invite substantially more knowledge–based inferences (Graesser, 1981; Graesser & Clark, 1985). Therefore, the narrative genre was selected in order to enhance the high–level comprehension processes of interest. In what follows we will summarise the general findings that motivate the aims of this research.

Inference making is an essential cognitive process for comprehension. Inferences are necessary for constructing a coherent mental representation (e.g., Graesser, et al., 1994; Magliano, et al., 1999; Zwaan & Radvansky, 1998); integrating current information to prior parts of the text and/or prior knowledge (e.g., Magliano, et al., 1999; Zwaan, et al., 1995); and providing explanatory arguments (Graesser, et al., 1994). However, although both text–based and knowledge–based inferences contribute to the construction of a coherent situation model (McNamara & Magliano, 2009), the role of the knowledge–based inferences has been only considered in few models of comprehension (e.g., Graesser, et al., 1994; Kintsch, 1988, 1998). Moreover, the importance of causality in inference generation has recently been stressed. For example, explanations have been related to causal inference (Johnson–Laird, et al., 2004; Sloman, 2005; Byrne, 2005; Walsh & Johnson–Laird, 2009); readers are faster and/or more accurate at answering comprehension questions when they have generated explanatory coherence (Graesser, et al., 1997; Magliano, et al., 1993; Singer, 1995); the elaboration of explanations may facilitate the prediction of future behaviours (Anderson & Ross, 1980; Einhorn & Hogarth, 1986; Lombrozo & Carey, 2006; Ross, Lepper, Strack, & Steinmetz, 1977); and the generation of both explanations and predictions is facilitated when there are strong causal constraints in text information rather than poor causal connections (e.g., Linderholm, 2002; Virtue, et al., 2006).

In accordance with prior findings, an interesting categorization of three types of knowledge–based inferences differing in their causal nature has been proposed (Trabasso & Magliano, 1996): explicative, associative and predictive inferences. The three types of inferences required to link text information with background knowledge, but explicative and predictive inferences also demand the integration of sentences across the text by means of causal (antecedent or consequent) relationships. Furthermore, the generation of inferences relies on memory processes by maintaining and processing information represented in working memory or by retrieving relevant information from long–term memory (e.g., Daneman & Green, 1986). In fact, several studies have demonstrated working memory differences in the ability to infer information (e.g., Daneman & Green, 1986; St. George, et al., 1997). Therefore, since explicative and predictive inferences require to connect (and thus, actively maintain) larger amounts of information from the text, we predicted a stronger influence of working memory capacity in the performance of these causally–constrained inferences than in inferences mainly generated from long–term memory (associative inferences). With this aim, we conducted the first study (Study 1) of the present research (see section 2.1.).

Besides inference making, comprehension monitoring is another high–level cognitive process that is crucial for reading. In order to incorporate explicit or inferential incoming information into the situation model readers must be aware of what they have read (e.g., Baker, 2002; Ruffman, 1996; Wagoner, 1983). More specifically, the literature on monitoring has differentiated two phases: the evaluation phase, which entails the detection of information that can be inconsistent; and the regulation phase, which occurs only when inconsistent information has been detected, and requires the reader to review and repair the inconsistency in the mental representation (e.g., Baker, 1985). Failures in the evaluation phase have been associated with less efficiency in constructing a coherent mental representation (Zwaan & Radvansky, 1998); and a poor ability in discriminating when they have comprehended accurately from when they have not (Hosseini & Ferrell, 1982). On the other hand, the repair function of the regulation phase has been related to the updating process (Hacker, 1998). For example, the revision process entails the encoding of the incoming information, the evaluation of inconsistent information and the replacement of outdated information with new information (Rapp & Kendeou, 2007). In relation to this process, many studies have reported failures to discard the no longer relevant information, even when the new information has been updated (e.g., Guéraud, et al., 2005; Hakala & O'Brien, 1995; Johnson & Seifert, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien, et al., 2010; O'Brien, et al., 1998; Rapp & Kendeou, 2007, 2009; van Oostendorp & Bonebakker, 1999).

Considering that readers must be able to maintain and process relevant information in working memory to detect an inconsistency between the current information and their memory representation (comprehension monitoring) and to replace no longer relevant information with new information (updating information), it is reasonable to think that this memory system is involved in both cognitive processes. Despite this, the literature investigating the relationship between working memory and comprehension monitoring in young adults has shown inconclusive results (e.g., De Beni, et al., 2007; Bohn-Gettler, Rapp, van den Broek, Kendeou, & White, 2011). In addition, although several studies have found that poor comprehenders are also poor at updating the contents of working memory (e.g., Carretti, et al., 2005; Palladino, et al., 2001), it is still unknown if readers with poor working memory are also poor at updating their situation model. A very influential approach demonstrating individual differences in comprehension has been the Structure–Building model (Gernsbacher, 1990, 1997). According to this view, consistent information facilitates the enhancement of the already activated mental representation, while inconsistent information forces the suppression of the ideas that are no longer relevant. Accordingly, it has been found that although poor skilled readers do not have problems enhancing their mental representation, they have problems suppressing no longer relevant information (e.g., Gernsbacher & Faust, 1991; Gernsbacher, et al., 1990). The same idea has been extrapolated to working memory differences in reading comprehension: poor working memory readers may have deficits inhibiting information that is irrelevant (De Beni, et al., 1998; Pimperton & Nation, 2010). Therefore, our second aim (Study 2) was to disentangle the interconnection between comprehension monitoring (evaluation phase) and updating information (regulation phase) at the situation model representation, investigating whether these processes depended on individual differences in working memory capacity. In fact, we were specifically interested in clarifying if working memory differences associated with these comprehension processes were restricted to the verbal domain without influence of the visuospatial domain (see section 2.1.).

Importantly, these processes combine during comprehension. For example, inference making and comprehension monitoring processes are needed when presenting an implicit character's goal (e.g., '*[Dick] had always been a real sun-worshipper*') followed by an action that is inconsistent (e.g., *[He]... asked for a plane ticket to Alaska*'; Poynor & Morris, 2003). Similarly, the combination of inference making and updating information processes is also possible. For example, if some information primes a specific concept (e.g., '*The bigger animal wanted to hunt the mouse*' primes the idea of '*cat*'), a subsequent inconsistent and implicit information with this idea (e.g., '*The bigger animal barked loudly*') should cause the detection of inconsistent information and further the replacement of the prior interpretation (e.g., '*cat*') with the new idea (e.g., '*dog*'). This is what we have called *inferential updating* and can be defined as the ability to replace an inference that is incompatible with new inferential information. In our third study (Study 3), we were interested to dissociate the interconnection between comprehension monitoring and updating information at the level of the situation model by requiring readers to perform an inferential updating task (see section 2.1.). In this study, we also predicted individual differences in working memory capacity associated with the inferential updating process since some studies have found a relationship between poor comprehension and poor working memory updating (e.g., Carretti, et al., 2005; Carretti, et al., 2010; Palladino, et al., 2001). We also tested whether these differences could be explained by a memory updating task, taking into account that this task has been defined as a measure of the central executive component of working memory (Morris & Jones, 1990).

2.1. AIMS OF THE RESEARCH

The general aim of the present thesis was to understand some of the high–level cognitive processes that are involved in the construction of the situation model, and their relationship with individual differences in working memory. To this purpose, we selected narrative texts to minimise comprehension problems that might arise through the lack of background knowledge, and to benefit the recall of information facilitating the generation of inferences. We will now describe the specific aims of the research and the experimental designs proposed to study these aims.

Using the categorization of knowledge–based inferences of Trabasso and Magliano (1996) Study 1 aimed to understand if working memory capacity is more involved in the performance of causal inferences (explicative and predictive inferences) compared to inferences that are mainly generated from long–term memory (associative inferences). To test this prediction, first we used the reading span task (Daneman & Carpenter, 1980) to select high and low working memory readers. Then, we evaluated participants in an inferential task where long narratives were presented and they had to answer off–line comprehension sentences. These comprehension sentences required verbatim information, or explicative, associative, and predictive inferential information. In this way, we compared the performance (accuracy and response latency) of high and low working memory readers in comprehension sentences demanding different types of knowledge–based inferences.

Study 2 aimed to disentangle the interrelation that underlies both comprehension monitoring (inconsistency detection) and updating information (replacement of no longer relevant information) processes, and their relation with working memory capacity. To investigate this question, readers were evaluated in an inferential monitoring task based on the contradiction paradigm, where we monitored readers' eye movements (reading times and regressions). Concretely, we presented short narratives in which the prior context primed a knowledge–based inference that subsequently could be confirmed by an expected concept, or disconfirmed by an unexpected concept. This manipulation allowed us to see if readers generated the inference and whether they were able to detect the inconsistency (comprehension monitoring). Additionally, a critical sentence was presented just below the narrative (at the same time), which included congruent or incongruent information with respect to the previous concept in the text. Readers were required to indicate if this sentence was true (congruent) or false (incongruent) by pressing one of two buttons. The critical sentence allowed us to measure if readers had updated their situation model during text reading. Furthermore, to explore if there are working memory differences in these processes and if these differences are specific of the verbal domain, we included working memory measures that tapped both the verbal domain (listening recall and backward digits recall tasks) and the visuospatial domain (odd one out and spatial recall tasks) by using the Automated Working Memory Assessment battery (Alloway, 2007).

Study 3 aimed to further clarify the influence of working memory capacity in the interconnection between comprehension monitoring and updating information by asking readers to perform an inferential updating task. We first evaluated participants working memory by using the reading span task (Daneman & Carpenter, 1980) and a memory updating task (Carretti, et al., 2010). More interesting, to explore the dynamic process of inferential updating, participants were evaluated in a situation model updating task. This task was similar to the paradigm of Study 2 but included some important changes. We presented short narratives in which the prior context primed a knowledge–based inference. However, instead of two possible explicit concepts, this time we presented three possible continuations: a neutral sentence, that did not offer any relevant information about the prior context; a no update sentence, where the information was implicitly related to the primed concept; and an update sentence, where the information was implicitly related to a new inference, requiring the reader to discard the prior wrong interpretation (inferential updating). This continuation sentence allowed us to measure (by reading times) if high and low working memory readers detected the inferential inconsistency. Furthermore, a subsequent final sentence included a disambiguating word that uncovered the real concept of the story. This explicit concept was always inconsistent with the prior wrong interpretation and consistent with the update sentence. The disambiguating word allowed us to measure (by means of event–related potentials or ERPs) what occurs when high and low working memory readers encounter inconsistent or already updated information.

To conclude, the construction of a coherent and integrate situation model involves cognitive processes such as inference making, comprehension monitoring and updating information. Some of these high–level processes entail the participation of working memory capacity by actively maintain and manipulating information, or even retrieving prior knowledge from long–term memory. In the present thesis we used narrative texts to investigate several aspects of the high–level processes and their relationship with individual differences in working memory. Concretely, in Study 1 we used three types of knowledge–based inferences that differed in their way to require the connection of text information. Inferential comprehension sentences demanding a causal connection in the text were predicted to be influenced by working memory capacity in comparison to inferential sentences that only demanded the activation of prior knowledge. Furthermore, in Study 2 and 3 we aimed to disentangle the processes of comprehension monitoring and updating information. Specifically, in Study 2 we used eye movements' technique to see if readers required the rereading of the text to answer critical sentences, allowing us to clarify whether they had updated their situation model. In addition, we evaluated both verbal and visuospatial working memory to explore whether differences in working memory were restricted to a specific domain. In Study 3 we used ERPs' technique to investigate the inferential updating process, and see if individual differences were also explained by a typical task used to evaluate the updating of the contents of working memory: memory updating task.

2. RESUMEN DE LA INVESTIGACIÓN

(OVERVIEW OF THE RESEARCH IN SPANISH)

A diferencia del procesamiento de palabra o de frase, el procesamiento de texto es una capacidad compleja que conlleva la construcción de una representación mental que contiene tanto la información del texto como el conocimiento previo del lector. Esta representación mental se conoce como modelo situacional (van Dijk y Kintsch, 1983) y es el punto de partida de esta investigación. La construcción de un modelo situacional coherente e integrado requiere de la participación de procesos cognitivos de alto nivel así como también de diferentes procesos de memoria. En la presente tesis doctoral nos centraremos en cómo estos procesos de alto nivel contribuyen a la comprensión de textos narrativos. Algunos estudios previos han mostrado que los textos narrativos tienen ciertas ventajas frente a los textos expositivos que pueden ser favorables para los propósitos de esta investigación. Por ejemplo, el contenido de las narraciones es a menudo más familiar y por tanto facilita el recuerdo (Graesser, Hauft–Smith, Cohen y Pyles, 1980; Kintsch y Young, 1984; Luszcz, 1993; Zabrucky y Moore, 1999), e incluso cuando se controla la familiaridad, las narraciones son más fáciles de comprender y recordar que los textos expositivos (Graesser, Hauft–Smith, Cohen y Pyles, 1980; Graesser y Riha, 1984). Además, puesto que las narraciones normalmente están repletas de escenas, objetos y personajes que desempeñan diferentes roles, intenciones y objetivos (p. ej. Graesser y cols., 1994; Radvansky y Dijkstra, 2007), ayudan a generar una mayor cantidad de inferencias basadas en el conocimiento (Graesser, 1981; Graesser y Clark, 1985). Por todo ello, en los estudios que describimos a continuación seleccionamos el género narrativo para resaltar los procesos de comprensión de alto nivel de interés. A continuación, resumiremos los hallazgos principales que motivan los objetivos de esta investigación.

La generación de inferencias es un proceso cognitivo esencial para la comprensión. Las inferencias son necesarias para construir una representación mental coherente (p. ej. Graesser y cols., 1994; Magliano y cols., 1999; Zwaan y Radvansky, 1998); integrar la información concurrente con partes previas del texto y/o con el conocimiento previo del lector (p. ej. Magliano y cols., 1999; Zwaan y cols., 1995); y proporcionar argumentos explicativos (Graesser y cols., 1994). Sin embargo, aunque tanto las inferencias basadas en el texto como las inferencias basadas en el conocimiento previo contribuyen a la construcción de un modelo situacional coherente (McNamara y Magliano, 2009), el papel de las inferencias basadas en el conocimiento previo sólo se ha tenido en cuenta en algunos modelos de comprensión (p. ej. Graesser y cols., 1994; Kintsch, 1988, 1998). Por otra parte, recientemente se ha acentuado la importancia de la causalidad en la generación de inferencias. Por ejemplo, se han relacionado las explicaciones con las inferencias causales (Johnson–Laird y cols., 2004; Sloman, 2005; Byrne, 2005; Walsh y Johnson–Laird, 2009); los lectores son más rápidos y más precisos contestando a preguntas de comprensión cuando consiguen generar coherencia explicativa (Graesser y cols., 1997; Magliano y cols., 1993; Singer, 1995); la elaboración de explicaciones puede facilitar la predicción de conductas futuras (Anderson y Ross, 1980; Einhorn y Hogarth, 1986; Lombrozo y Carey, 2006; Ross, Lepper, Strack y Steinmetz, 1977); y tanto la generación de explicaciones como la de predicciones se facilita cuando hay restricciones causales fuertes en la información del texto frente a cuando sólo existen conexiones causales pobres (p. ej. Linderholm, 2002; Virtue y cols., 2006).

De acuerdo con estudios previos, se ha propuesto una categorización de tres tipos de inferencias basadas en el conocimiento previo que difieren en su naturaleza causal (Trabasso y Magliano, 1996): inferencias explicativas, asociativas y predictivas. Los tres tipos de inferencias requieren la unión de información del texto con el conocimiento que tiene el lector, pero las inferencias explicativas y predictivas también demandan la integración de diferentes frases a lo largo del texto por medio de relaciones causales (antecedente o consecuente). A su vez, la generación de inferencias se basa en procesos de memoria ya sea mediante el mantenimiento y procesamiento de la información representada en memoria de trabajo, o mediante la recuperación de información relevante desde memoria a largo plazo (p. ej. Daneman y Green, 1986). De hecho, varios estudios han demostrado diferencias individuales en memoria de trabajo en relación a la capacidad de inferir información (p. ej. Daneman y Green, 1986; St. George y cols., 1997). Por tanto, ya que las inferencias explicativas y predictivas necesitan conectar (y en tal caso, mantener activamente) una gran cantidad de información proveniente del texto, nosotros esperábamos una mayor influencia de la capacidad de memoria de trabajo en la ejecución de las inferencias restringidas causalmente que en las inferencias generadas principalmente desde memoria a largo plazo (inferencias asociativas). Con este objetivo, llevamos a cabo el primer estudio (Estudio 1) de la presente investigación (véase el apartado 2.1.).

Además de la generación de inferencias, la monitorización de la comprensión es otro proceso cognitivo de alto nivel que es crucial para la lectura. Con el objetivo de incorporar en el modelo situacional la información explícita o inferencial que va llegando, los lectores deben ser conscientes de lo que están leyendo (p. ej. Baker, 2002; Ruffman, 1996; Wagoner, 1983). Específicamente, la literatura sobre monitorización ha diferenciado dos fases: la fase de evaluación, la cual conlleva la detección de información que puede ser inconsistente; y la fase de regulación, la cual ocurre sólo cuando se ha detectado información inconsistente, y cuando requiere que el lector revise y repare dicha inconsistencia en su representación mental actual (p. ej. Baker, 1985). Los fallos en la fase de evaluación han sido asociados a una baja eficiencia en la construcción de una representación mental coherente (Zwaan y Radvansky, 1998); y una pobre capacidad para discriminar cuándo se ha comprendido con precisión y cuándo no se ha comprendido (Hosseini y Ferrell, 1982). Por otra parte, la función de reparación de la fase de regulación se ha relacionado con el proceso de actualización (Hacker, 1998). Por ejemplo, el proceso de revisión conlleva la codificación de la información entrante, la evaluación de la información inconsistente y el reemplazo de la información obsoleta por información nueva (Rapp y Kendeou, 2007). En relación a este proceso, muchos estudios han informado de fallos para descartar la información que ya no es relevante, incluso cuando la nueva información ha sido incorporada (p. ej. Guéraud y cols., 2005; Hakala y O'Brien, 1995; Johnson y Seifert, 1998, 1999; Kendeou y van den Broek, 2007; O'Brien y cols., 2010; O'Brien y cols., 1998; Rapp y Kendeou, 2007, 2009; van Oostendorp y Bonebakker, 1999).

Considerando que los lectores deben ser capaces de mantener y procesar información relevante en memoria de trabajo para detectar una inconsistencia entre la información actual y su representación mental (monitorización de la comprensión), así como para reemplazar información que no es relevante por más tiempo por información nueva (actualización de la información), es razonable pensar que este sistema de memoria participa en ambos procesos cognitivos. A pesar de esto, los estudios investigando la relación entre memoria de trabajo y monitorización de la comprensión en adultos jóvenes no han mostrado resultados concluyentes (p. ej. De Beni y cols., 2007; Bohn-Gettler, Rapp, van den Broek, Kendeou y White, 2011). Además, aunque distintos estudios han encontrado que los lectores con pobre comprensión son también pobres actualizando los contenidos en memoria de trabajo (p. ej. Carretti y cols., 2005; Palladino y cols., 2001), se desconoce todavía si los lectores con baja memoria de trabajo son también pobres actualizando su modelo situacional. Una propuesta muy influyente que ha demostrado diferencias individuales en comprensión ha sido el modelo de "Construcción de Estructuras" (Structure–Building model en inglés; Gernsbacher, 1990, 1997). De acuerdo con esta propuesta, la información consistente facilita el aumento de la representación mental ya activada, mientras que la información inconsistente fuerza la supresión de las ideas que no son relevantes por más tiempo. En relación a esto, se ha encontrado que aunque los lectores con pobres habilidades no presentan problemas aumentando su representación mental, sí tienen problemas suprimiendo información que es irrelevante (p. ej. Gernsbacher y Faust, 1991; Gernsbacher y cols., 1990). La misma idea se ha extrapolado a las diferencias de memoria de trabajo encontradas en la comprensión lectora: los lectores con pobre memoria de trabajo podrían tener déficits inhibiendo información irrelevante (De Beni y cols., 1998; Pimperton y Nation, 2010). Por tanto, nuestro segundo objetivo (Estudio 2) fue desenmarañar la interconexión existente entre la monitorización de la comprensión (fase de evaluación) y la actualización de la información (fase de regulación) a un nivel de representación de modelo situacional, investigando si estos procesos dependían de diferencias individuales en la capacidad de memoria de trabajo. De hecho, estábamos particularmente interesados en clarificar si estas diferencias asociadas a los procesos de comprensión se limitaban al dominio verbal de memoria de trabajo, sin influencia del dominio visoespacial (véase el apartado 2.1.).

De especial interés es el hecho que los procesos anteriormente descritos pueden combinarse durante la comprensión. Por ejemplo, los procesos de generación de inferencias y monitorización de la comprensión son necesarios cuando se presenta el objetivo de un personaje de forma implícita (p. ej. '*[Dick] había sido siempre un auténtico adorador del sol*') seguido de una acción que es inconsistente (p. ej. '*[Él]... pidió un billete de avión para Alaska*'; Poynor y Morris, 2003). De forma similar, la combinación de los procesos de generación de inferencias y actualización de la información también es posible. Por ejemplo, si cierta información facilita un concepto específico (p. ej. '*Un animal más grande quería cazar al ratón*' facilita la idea de '*gato*'), una información inconsistente e implícita con esta idea presentada posteriormente (p. ej. '*El animal más grande ladró fuertemente*') debería causar la detección de información inconsistente y el reemplazo de la primera interpretación (p. ej. '*gato*') por la nueva (p. ej. '*perro*'). Esto es lo que nosotros hemos llamado *actualización inferencial* y puede definirse como la capacidad de reemplazar una inferencia que es incompatible con nueva información inferencial. En nuestro tercer estudio (Estudio 3), estábamos interesados en disociar la interconexión entre la monitorización de la comprensión y la actualización de la información a nivel de modelo situacional, requiriendo a los lectores llevar a cabo una tarea de actualización inferencial (véase el apartado 2.1.). Una vez más, hipotetizamos diferencias individuales en la capacidad de memoria de trabajo asociadas al proceso de actualización inferencial, debido a la relación encontrada por algunos estudios entre una pobre comprensión y una pobre actualización en memoria de trabajo (p. ej. Carretti y cols., 2005; Carretti y cols., 2010; Palladino y cols., 2001). Además, evaluamos si estas diferencias podían ser explicadas por una tarea de actualización en memoria, teniendo en cuenta que esta tarea ha sido definida como una medida del ejecutivo central de memoria de trabajo (Morris y Jones, 1990).

2.1. OBJETIVOS DE LA INVESTIGACIÓN

El objetivo general de la presente tesis fue entender algunos de los procesos cognitivos de alto nivel que participan en la construcción del modelo situacional, y sus relaciones con posibles diferencias individuales en memoria de trabajo. Con éste propósito, seleccionamos textos narrativos para minimizar los problemas de comprensión que podían surgir a través de la falta de conocimiento previo, y para beneficiar el recuerdo de información facilitando la generación de inferencias. A continuación describiremos los objetivos específicos de la investigación y los diseños experimentales propuestos para estudiar estos objetivos.

Usando la categorización de inferencias basadas en el conocimiento previo propuesta por Trabasso y Magliano (1996), el Estudio 1 tuvo como objetivo entender si la capacidad de memoria de trabajo está más implicada en la ejecución de inferencias causales (inferencias explicativas y predictivas) que en la ejecución de inferencias que son generadas principalmente desde memoria a largo plazo (inferencias asociativas). Para poner a prueba esta predicción, primero usamos la tarea de amplitud lectora (Daneman y Carpenter, 1980) para seleccionar a lectores con alta y baja memoria de trabajo. Posteriormente, evaluamos a los participantes en una tarea inferencial donde presentamos narraciones con diferentes párrafos y los sujetos debían responder a frases de comprensión de forma off–line. Estas frases de comprensión requerían información literal, o información inferencial explicativa, predictiva o asociativa. De esta forma, comparamos la ejecución (aciertos y latencia de respuesta) de lectores con alta y baja memoria de trabajo en frases de comprensión que demandaban diferentes tipos de inferencias basadas en el conocimiento previo.

El Estudio 2 tuvo como objetivo desenmarañar la interrelación que subyace a los procesos de monitorización de la comprensión (detección de información inconsistente) y actualización de la información (reemplazo de información que no es relevante por más tiempo), y sus relaciones con la capacidad de memoria de trabajo. Para investigar esta cuestión, los lectores fueron evaluados en una tarea de monitorización inferencial basada en el paradigma de contradicción, donde registramos los movimientos oculares de los participantes (tiempos de lectura y regresiones). Concretamente, presentamos textos narrativos cortos en los que el contexto previo facilitaba una inferencia basada en el conocimiento previo que posteriormente podía ser confirmada por un concepto esperado, o desconfirmada por un concepto inesperado. Esta manipulación nos permitió ver si los lectores generaron la inferencia y si fueron capaces de detectar la inconsistencia (monitorización de la comprensión). Además, una frase crítica se presentó justo debajo de cada texto (al mismo tiempo), la cual incluía información congruente o incongruente con respecto al concepto presentado previamente en el texto. Los lectores debían indicar si esta frase era verdadera (congruente) o falsa (incongruente) presionando una de dos teclas. La frase crítica nos permitió medir si los lectores habían actualizado su modelo situacional durante la lectura del texto. A su vez, para explorar si existen diferencias en memoria de trabajo en estos procesos, y si estas diferencias son específicas del dominio verbal, incluimos medidas de memoria de trabajo abarcando tanto el dominio verbal (tareas de recuerdo auditivo y recuerdo de dígitos hacia atrás) como el dominio visoespacial (tareas de "señalar el diferente" o "odd one out" y recuerdo espacial) mediante la batería de Evaluación de Memoria de Trabajo Automatizada (Automated Working Memory Assessment battery; Alloway, 2007).

El Estudio 3 tuvo como objetivo clarificar un poco más la influencia de la capacidad de memoria de trabajo en la interconexión entre la monitorización de la comprensión y la actualización de la información mediante el proceso de actualización inferencial. Primero evaluamos la memoria de trabajo de los participantes usando tanto la tarea de amplitud lectora (Daneman y Carpenter, 1980) como la tarea de actualización en memoria (Carretti y cols., 2010). Posteriormente, para explorar el proceso dinámico de actualización inferencial, los participantes fueron evaluados con una tarea de actualización del modelo situacional. Esta tarea fue parecida al paradigma del Estudio 2, pero incluyó algunos cambios importantes. Una vez más presentamos textos narrativos cortos en los cuales el contexto previo facilitaba una inferencia basada en el conocimiento previo. Sin embargo, en vez de dos posibles conceptos explícitos, esta vez presentamos tres posibles continuaciones: una frase neutra, que no ofreció información relevante sobre el contexto previo; una frase de no actualización, donde la información estaba relacionada implícitamente con el concepto facilitado; y una frase de actualización, donde la información estaba relacionada implícitamente a una nueva inferencia, demandando que el lector descartara la interpretación errónea previa (actualización inferencial). Esta frase de continuación nos permitió medir (mediante tiempos de lectura) si los lectores con alta y baja memoria de trabajo detectaron la inconsistencia inferencial. A su vez, una frase final posterior incluyó una palabra desambiguante que descubría el concepto real de la historia. Este concepto explícito fue siempre inconsistente con la interpretación errónea de la introducción y consistente con la frase de actualización. Por tanto, la palabra desambiguante nos permitió medir (por medio de potenciales relacionados a eventos o ERPs) qué ocurre cuando lectores con alta y baja memoria de trabajo encuentran información inconsistente o información que ya deberían haber actualizado.

A modo de conclusión, la construcción de un modelo situacional coherente e integrado conlleva procesos cognitivos tales como la generación de inferencias, la monitorización de la comprensión y la actualización de la información. Algunos de estos procesos de alto nivel requieren de la participación de la capacidad de memoria de trabajo mediante el mantenimiento activo y la manipulación de información, o incluso mediante la recuperación de conocimiento previo desde memoria a largo plazo. En la presente tesis doctoral usamos textos narrativos para investigar varios aspectos de los procesos de alto nivel y sus relaciones con las diferencias individuales en memoria de trabajo. Concretamente, en el Estudio 1 usamos tres tipos de inferencias basadas en el conocimiento que diferían en su manera de requerir la unión de información en el texto. En este sentido, esperábamos una mayor influencia de la memoria de trabajo en aquellas frases de comprensión inferencial que demandaban una conexión causal en el texto, frente a las que sólo demandaban la activación de conocimiento previo. Por su parte, en los Estudios 2 y 3 nos propusimos disociar los procesos de monitorización de la comprensión y actualización de la información. Específicamente, en el Estudio 2 usamos la técnica de movimientos oculares para ver si los lectores necesitaban releer el texto para contestar a las frases críticas, permitiéndonos clarificar si habían o no actualizado su modelo situacional. Además, evaluamos los dominios verbal y visoespacial de memoria de trabajo para explorar si las diferencias en memoria de trabajo son de dominio específico. En el Estudio 3 usamos la técnica de ERPs para investigar el proceso de actualización inferencial, y si las diferencias individuales se explicaban también mediante una tarea típica usada para evaluar la actualización de los contenidos de memoria de trabajo: la tarea de actualización en memoria.

3. EXPERIMENTAL STUDIES

STUDY 1

The role of Working Memory in Inferential Sentence Comprehension

Pérez, A., Paolieri, D., Macizo, P., & Bajo, T. (2014). The role of working memory in inferential sentence comprehension. *Cognitive Processing*. 10.1007/s10339–014–0611–7

Abstract

Existing literature on inference making is large and varied. Trabasso and Magliano (1996) proposed the existence of three types of inferences: explicative, associative and predictive. In addition, the authors suggested that these inferences were related to working memory. In the present experiment we investigated whether working memory capacity plays a role in our ability to answer comprehension sentences that require text information based on these types of inferences. Participants with high and low working memory span read two narratives with four paragraphs each. After each paragraph was read, they were presented with four true/false comprehension sentences. One required verbatim information and the other three implied explicative, associative and predictive inferential information. Results demonstrated that only the explicative and predictive comprehension sentences required working memory: participants with high verbal working memory were more accurate in giving explanations and also faster at making predictions relative to participants with low verbal working memory span; in contrast, no working memory differences were found in the associative comprehension sentences. These results are interpreted in terms of the causal nature underlying these types of inferences.

Keywords: working memory; comprehension sentences; inference making; text comprehension.

3.1.1. Introduction

Text comprehension requires the construction of a mental representation or situation model that combines the information given in the text with reader's prior knowledge in order to accurately understand the text's meaning (van Dijk & Kintsch, 1983). In this structural process, the reader needs to use multiple high–level skills as inferences, in order to establish relationships between explicit discourse elements, to anticipate possible events, and/or to embellish text information (e.g., Graesser, Singer, & Trabasso, 1994; Zwaan & Radvansky, 1998). According to Radvansky and Dijkstra (2007) the comprehension of narrative texts requires the building of a situation model where the characters, their interactions, their goals and actions, as well as the physical context of the story are represented. In this context, narratives seem to be a good scene to explore how readers extract inferential information.

Inference classifications are vast and numerous. A general distinction between on–line and off–line inferences can be made (e.g., van den Broek, Lorch, Linderholm, & Gustafson, 2001), the main difference being that on–line inferences occur during reading as part of comprehension processes, while off–line inferences take place after reading and as the product of comprehension. Despite the importance of studies focused on on–line inferences during the late 80s and 90s (e.g., Graesser & Clark, 1985; Graesser et al., 1994), the study of inference making using off–line measures has also gained importance since it reflects the result of a wide range of processes that take place at the situation model representation (e.g., McKeown, Beck, & Blake, 2009; van den Broek, Tzeng, Risden, Trabasso, & Basche, 2001), not forgetting that the comprehension of students is typically assessed off–line. Additionally, a more specific inference's taxonomy distinguishes between text–based and knowledge–based inferences (Kintsch, 1988, 1998). Text–based inferences require the connection of specific information from the text. They are classified as local or global inferences depending on the distance between the information that is connected (close or distant, respectively; Graesser, Wiemer–Hastings, & Wiemer–Hastings, 2001). On the other hand, knowledge–based inferences entail the combination of text information and reader's prior knowledge, which can also be classified according to their relation to text information (e.g., Cain & Oakhill, 2006; Rapp, van den Broek, McCaster, Kendeou, & Espin, 2007) or their causal direction in the story (Trabasso & Magliano, 1996; van den Broek, Fletcher, & Risden, 1993).

Trabasso and Magliano (1996) have proposed an interesting classification of three types of knowledge–based inferences: explicative, associative and predictive. Explicative or backward inferences usually answer '*why*' questions that can be related with goals or intentions, physical causes or conditions that let something to be possible (e.g., Narvaez, van den Broek & Ruiz, 1999). Their function is to explain information from the text by means of causal antecedents (e.g., if '*Tom has been running under the sun to arrive on time. Once there, Tom ordered a glass of water from the waitress*' an explicative inference to the question '*why did Tom order a glass of water?*' would be that '*Tom was thirsty*'). Considering that an explanation requires connecting several ideas of a text, explicative inferences are related to those inferences improving the local and/or global story's coherence, which are usually drawn during reading (e.g., Beeman, 1993; Beeman, Browden, Gernsbacher, 2000). Explicative inferences play an essential role in comprehension since language has been proposed to be essentially explanation based (Graesser et al., 1994; Magliano, Baggett, Johnson, & Graesser, 1993). Associative or concurrent inferences take into account the current information from the text (focal sentence) to relate it with the reader's prior knowledge about the general features and functions of a character, concept or context (e.g., '*Tom was in a bar/restaurant*'). In addition, contrarily to explanations, evidence has demonstrated that associations are not commonly activated during normal reading (e.g., Graesser et al., 1994; McKoon & Ratcliff, 1992). Due to the general nature of the associations, this category seems to be a mixture of information where more specific types of inferences such as instrumental (e.g., Harmon–Vukic, Guéraud, Lassonde, & O'Brien, 2009), instantiations (e.g., Oakhill, 1983) or those referring to spatial locations (e.g., Morrow, Bower, & Greenspan, 1989) are included. Finally, predictive or forward inferences have been described as the process to infer about future outcomes or anticipate upcoming events in a story (e.g., Beeman et al., 2000). Thus, they are generated when the current information from the text forces the anticipation of an event or causal consequence (e.g., '*The waitress will bring the glass of water, and Tom will drink it*') that may or may not be explicitly confirmed by the text. Predictions or expectations are not usually generated on–line, however this can occurs if they are highly constrained by the text and the related information is available from long–term memory or maintained in working memory (e.g., Calvo, Castillo, & Schmalhoffer, 2006; Peracchi & O'Brien, 2004). It is important to note that these three types of inferences require to link text information with background knowledge; however, explicative and predictive inferences are involved in the integration of sentences across the text, while associative inferences do not. This distinction has to do with the causal nature of explanations (based on causal antecedents) and predictions (based on causal consequents). In narratives, the construction of an integrated situation model requires connections across sentences that are commonly achieved by making causal inferences (e.g., Suh & Trabasso, 1993) which contributed to the integration of text information. In contrast, associative inferences connect the current text information with prior knowledge without establishing causal relationships across the text (e.g., Trabasso & Magliano, 1996), although they can help to integrate text information by long–term memory semantic associations (McKoon & Ratcliff, 1992). Interestingly, it has been demonstrated that the causal constraints of the text affect the activation of both explicative and predictive inferences, with stronger influence in the latter (e.g., Linderholm, 2002; Peracchi & O'Brien, 2004; Virtue, van den Broek, & Linderholm, 2006). For example, Virtue et al. (2006) found that the activation of bridging (backward) and predictive inferences was more facilitated when they presented stronger causal constraints relative to weaker causal constraints. However, the activation of these types of inferences seems to differ according to brain hemispheres: bridging inferences are better generated in the left hemisphere, whereas predictive inferences are facilitated in the right hemisphere[3] (see also Joss & Virtue, 2009). Virtue et al. (2006) explained these results in terms of stronger semantic connections between concepts in the left hemisphere and larger semantic overlap in the right hemisphere.

Working memory capacity (e.g., Baddeley & Hitch, 1974; Baddeley, 2000) is conceived as a mental work space where text information is maintained, processed and integrated with information from long–term memory during and after reading.

[3] They also found working memory differences in the strength of the causal constraints depending on brain hemispheres.

In fact, working memory span (e.g., measured with the reading span test, Daneman & Carpenter, 1980) broadly correlates with language and reading comprehension (e.g., Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Merikle, 1996). Moreover, working memory has been related to high reading skills (e.g., Cain, Oakhill, & Bryant, 2004), and inference generation (e.g., St. George, Mannes, & Hoffman, 1997; Virtue, van den Broek, & Linderholm, 2006). In addition, there is evidence indicating that working memory influences off–line inference making (e.g., Chrysochoou, Bablekou, & Tsigilis, 2011). However, some studies have found that working memory span is not directly related to situation model comprehension (e.g., Radvansky & Copeland, 2004), which leaves open the question of whether working memory may help in the construction of a mental representation facilitating in this way the answer to inferential comprehension sentences.

Using thinking–aloud protocols in narratives, Trabasso and Magliano (1996) investigated the relationship between the generation of explicative, associative and predictive inferences during reading and three working memory processes: a) activation of relevant world knowledge; b) maintenance of information from the immediately prior sentence; and c) retrieval of information from a long–term memory representation of the text. Participants were asked to stop reading and verbalize their thoughts after each sentence of the text. These verbalized thoughts were then classified according to the type of inference and working memory process. Their results revealed that the explicative inferences were the most reported type of inference followed by associative and predictive inferences. In addition, the three working memory processes (activation, maintenance and retrieval) were highly involved in drawing this type of inference indicating an important role of working memory in inferential processing, especially when explicative inferences were involved. Even though these results were quite innovative, the on–line think–aloud methodology forced a sentence by sentence evaluation which might not capture the process of maintaining information in working memory during the reading of the text. Moreover, the memory operations investigated by Trabasso and Magliano (1996) were established from participant's verbalizations, so the lack of an independent measure of working memory might weaken the conclusions of this study.

Therefore, in order to elucidate if working memory influences the reader's ability to answer comprehension sentences by the construction of a situation model, we first evaluated working memory capacity by an independent measure and then inference making by an off–line methodology.

The current study is theoretically framed in Trabasso and Magliano's (1996) inferential classification because the authors argue that different memory processes underlie the type of inference generated during reading. Specifically, we focused on the relationship between the verbal domain of working memory capacity (measured with the reading span task), and the comprehension product (measured with off–line comprehension sentences) of three types of inferences: explicative, associative and predictive. In line with the results of Trabasso and Magliano (1996), we predicted working memory differences depending on the type of comprehension sentences: high verbal working memory participants would answer sentences involving explicative and predictive inferences more efficiently than low verbal working memory participants, since these causal inferences require to maintain a larger amount of text information (connections across sentences) to integrate it into a coherent situation model. In contrast, high and low working memory participants should not differ when sentences involving associative inferences are presented since their generation mainly relies on background knowledge and they do not require connections across the text.

3.1.2. Method

Participants

Seventy–four secondary and undergraduate students from the city of Granada (Spain) with a mean age of 22 years old (range: 16–42 years) participated for either course credits or money. All were native Spanish speakers. After they performed the reading span task, only participants with extreme working memory scores (see below) were selected to participate in the inference task.

Materials

Reading span task. We used a Spanish version of Daneman and Carpenter's (1980) reading span test previously used in our laboratory (Macizo & Bajo, 2006). In this test, participants were instructed to read sets of sentences presented one–by–one in the middle of the screen and to recall the last sentence word at the end of each set. Participants could recall in whatever order with the exception that they could not start with the last word of the last sentence. There were five levels of increasing difficulty from sets of two sentences to sets of six sentences. Each level included five sets of sentences. A level was considered correct if participants correctly recalled each last word of at least three out of five sets of sentences. The final reading span was the largest level that participants passed correctly. An additional 0.5 point was added to the final score if participants recalled two out of five sets in the last level.

Inferential task. We used the Spanish version of two stories extracted from different narrative books published in Spanish (Allende, 1989; Fuentes, 1995) and English (Adam, 1999; Peden, 1999). These texts were composed of four–paragraphs with a mean number of words of 109 per paragraph. Four comprehension sentences followed each paragraph. The sentences were constructed so that they conformed the features described by Trabasso and Magliano (1996) for the three types of inferences (see Table 1 for examples): a) explicative inferential sentences always referred to inferential information that resolved a 'why' question and that required, for example, understanding the impression of a character (e.g., '*Los hombres pálidos eran cobardes porque cazaban con pólvora*', in English '*The pale men were coward because they hunted with powder*'); b) associative inferential sentences were always related to the general context or to specific objects and features of the characters (e.g., '*Los cazadores eran torpes al andar por el uso de calzado*', in English '*The hunters were clumsy when they walked because they used footwear*'); and c) predictive inferential sentences would always refer to a character intention or to hypothetic case that may occur later in the story (e.g., '*Los cazadores pretendían comerciar con las piedras que encontrasen*', in English '*The hunters expected to trade with the stones that they would find*'). It could be thought that predictive inferential sentences can be answered as explicative. However, despite the issue that a statement can work as an explanation, the information relative to our predictive questions always required deducing new events that were not described in the paragraph. In addition, in order to ensure that participants were understanding the actual information in the text, we added sentences that included *verbatim* information from the text and that, therefore, did not demand inferential information as it was explicit in the paragraph (e.g., '*Los hombres pálidos hablaban de sus dioses*', in English '*The pale men spoke about their Gods*'). For every comprehension sentence participants had to answer 'yes', if they thought the sentence was true according to the story, or 'no' if they believed it was false. Two versions of each comprehension sentence were created: one was true, and the other false (see Table 1; see Appendix B for full materials, p. 193). The accuracy and response latency to each comprehension sentence was measured for later analyses.

Table 1. Example of a paragraph presented in the inferential task along with the four types of comprehension sentences (explicative, associative, verbatim and predictive).

One day a group of the pale men came to our village. They hunted with powder, from far away, skill or courage; they could not climb a tree or spear a fish in the water; they moved clumsily through the jungle, they were always getting tangled in their packs, their weapons, even their own feet. They did not clothe themselves in air, as we do, but wore wet and stinking clothing; they were dirty and they did not know the law of decency, but they insisted on telling us of their knowledge and their gods. We compared them with what we had been told about the white men, and we verified the truth of that gossip. Soon we realized that these men were not missionaries, or soldiers or rubber collectors: they were mad. They wanted the land; they wanted to carry away the wood; they were also searching for stones. We explained that the jungle is not something to be tossed over your shoulder and transported like a dead bird, but they did not want to hear our arguments.

	Comprehension sentences	**Answer**
Explicative	The pale men were *coward* because they hunted with powder.	Yes
	The pale men were *brave* because they hunted with powder.	No
Associative	The hunters were *clumsy* when they walked because they used footwear.	Yes
	The hunters were *agile* when they walked because they used footwear.	No
Verbatim	The pale men spoke about their *gods*.	Yes
	The pale men spoke about their *ancestors*.	No
Predictive	The hunters expected to *trade* with the stones that they would find.	Yes
	The hunters expected to *make fire* with the stones that they would find.	No

To provide empirical confirmation that participants were activating the inferences that we provided in our inferential sentences, we conducted a pilot study previous to the current study. For each inferential sentence an open question was constructed: explicative (e.g., '*¿Por qué el narrador opina que los hombres pálidos no tienen valor?*', in English '*Why does the narrator believe that the pale men are coward?*'); associative (e.g., '*¿A qué se refiere el narrador con que los cazadores llevaban enredados los pies?*', in English '*Why does the narrator say that the hunters had tangled feet?*'); and predictive (e.g., '*¿Para qué querrán los cazadores las piedras?*', in English '*What will the hunters do with the stones?*'). Participants were instructed to provide an open answer to each of these questions while they could still see the story. This methodology was used to ensure that their answers were not affected by their memory abilities. Seven participants completed this pilot task. They were shown the four paragraphs of the two narrative texts and they answered 32 open questions (16 from each text). In the current experiment we used only sentences whose responses in the pilot study were associated to inferential knowledge by a minimum of four out of seven participants. Results of the one–way ANOVA performed on the correct responses for each inferential open question (explicative, M = 6.14, SD = 1.07; associative, M = 6.29, SD = 0.95; and predictive, M = 6.86, SD = 1.35) showed no significant differences, $F(2, 12) = 1.06$, $p = .38$.

Procedure

The actual experiment was carried out in two individual sessions. In the first session, we presented the reading span task (Daneman & Carpenter, 1980) and it took approximately 10–15 minutes. Participants were instructed to recall the last word of each sentence and before each block, they were informed of the number of sentences (and words to recall) in the trial. Participants read each sentence at their own pace. At the end of the trial, a white screen appeared and participants said aloud the words that they could remember. A practice trial preceded the experimental trials. The scores of the reading span task were used to divide participants into two groups: low span group (span of 2 or less) and high span group (3.5 or more) in order to maximize working memory differences (King & Just, 1991; Waters & Caplan, 1996). A t–test comparison between working memory groups revealed no significant differences in age, $t(15) = 0.56$, $p = .58$. In the second session, only participants with low and high working memory spans were tested in the inferential task. In this task, the four paragraphs composing each text were individually presented. Participants were asked to read the paragraph at their own pace and once they finished it, they had to press a key after which the paragraph disappeared and the four comprehension sentences were presented one–by–one. They were asked to decide if each sentence was true or false regarding the information of the paragraph by pressing the corresponding key on the computer keyboard without any time pressure. The part of the text containing the information necessary to answer the sentences (see underlined text in Table 1) was counterbalanced across paragraphs for both texts so they appeared at the beginning, middle or the end of the paragraph with the same number of times for each type of inference. We did this to prevent any possible benefit of maintaining information in working memory. The same number of participants completed each version of the comprehension sentences. The order of presentation of the text and the true/false version of the sentence (minimum criteria of 25% being true or false) was also counterbalanced. To ensure that all participants understood the task, at the beginning of the experimental session, they were presented with a practice paragraph followed by four comprehension sentences. This paragraph and comprehension sentences were never used in the main experiment.

3.1.3. Results

One participant was eliminated due to a high error rate on the comprehension sentences (more than 50%), and two more due to high rates of outliers data (at least 75%) using the Box–Whisker plot. Therefore, we report statistical analyses for the correct responses of thirty–three participants (16 low and 17 high working memory span). The mean span of words recalled for the high working memory group was 4.12 (*SD* = 0.70; range = 3.5–6) and for the low working memory group was 1.84 (*SD* = 0.35; range = 1–2). Memory group was treated as an independent variable in the analyses reported below. In the inferential task, our dependent variables were the percentage of correct answers (accuracy) and the response latency (in milliseconds) to the comprehension sentences. Outlier data per condition and group was replaced by the mean in accuracy (2.86%) and response latency (3.57%) (e.g., Mundfrom & Whitcomb, 1998).

A mixed model ANOVA with type of comprehension sentence (verbatim, associative, explicative and predictive) and working memory group (high vs. low) was performed on both accuracy and response latency[4].

Accuracy. There was a main effect of type of sentence, $F(3, 93) = 5.51$, $p < .01$, $\eta_p^2 = .151$, with higher percentage of correct responses for verbatim sentences than for inferential sentences (associative, $F(1, 31) = 7.39$, $p < .05$; explicative, $F(1, 31) = 13.01$, $p < .01$; predictive, $F(1, 31) = 9.44$, $p < .01$) without significant differences among them (associative and explicative, $F(1, 31) = 1.33$, $p > .05$; associative and predictive, $F(1, 31) = 1.49$, $p > .05$; explicative and predictive, $F(1, 31) = 0.01$, $p > .05$). The main effect of group was not significant, $F(1, 31) = 0.79$, $p > .05$, but there was a significant type of sentence x group interaction, $F(3, 93) = 3.71$, $p < .05$, $\eta_p^2 = .11$. Planned comparisons revealed a significant difference between groups for explicative inferential sentences, $F(1, 31) = 5.45$, $p < .05$, where the group with high working memory had more correct responses (84.19%; $SD = 8.23$) than the low working memory group (73.44%; $SD = 17.00$). No other planned comparisons were significant (verbatim, $F(1, 31) = 1.20$, $p > .05$; associative, $F(1, 31) = 2.82$, $p > .05$; predictive, $F(1, 31) = 0.36$, $p > .05$) (see Figure 5, panel a).

Response latency. Again, there was a main effect of the type of sentence, $F(3, 93) = 35.55$, $p < .001$, $\eta_p^2 = .53$, with faster responses in the verbatim condition than in the inferential conditions (associative, $F(1, 31) = 18.62$, $p < .001$; explicative, $F(1, 31) = 63.46$, $p < .001$; predictive, $F(1, 31) = 94.05$, $p < .001$). Moreover, the associative inferential sentences were faster compared to both the explicative, $F(1, 31) = 18.05$, $p < .001$, and the predictive inferential sentences, $F(1, 31) = 25.97$, $p < .001$, which in turn did not differ from each other, $F(1, 31) = 3.49$, $p > .05$. The main effect of group was not significant, $F(1, 31) = 1.02$, $p > .05$, but again there was a significant type of sentence x group interaction, $F(3, 93) = 4.98$, $p < .01$, $\eta_p^2 = .14$. Planned comparisons revealed a significant difference between both working

[4] The same ANOVA without outlier data also demonstrated significant interactions in both accuracy, $F(3, 81) = 3.21$, $p < .05$, $\eta_p^2 = .11$; and response latency, $F(3, 78) = 2.83$, $p < .05$, $\eta_p^2 = .10$.

memory groups in the predictive inferential sentences, $F(1, 31) = 10.01$, $p < .01$, where the high working memory group was faster (5212 ms, $SD = 1145$) than the low working memory group (6458 ms; $SD = 1115$). There were no other significant planned comparisons (verbatim, $F(1, 31) = 0.00002$, $p > .05$; associative, $F(1, 31) = 0.19$, $p > .05$; explicative, $F(1, 31) = 0.30$, $p > .05$) (see Figure 5, panel b).

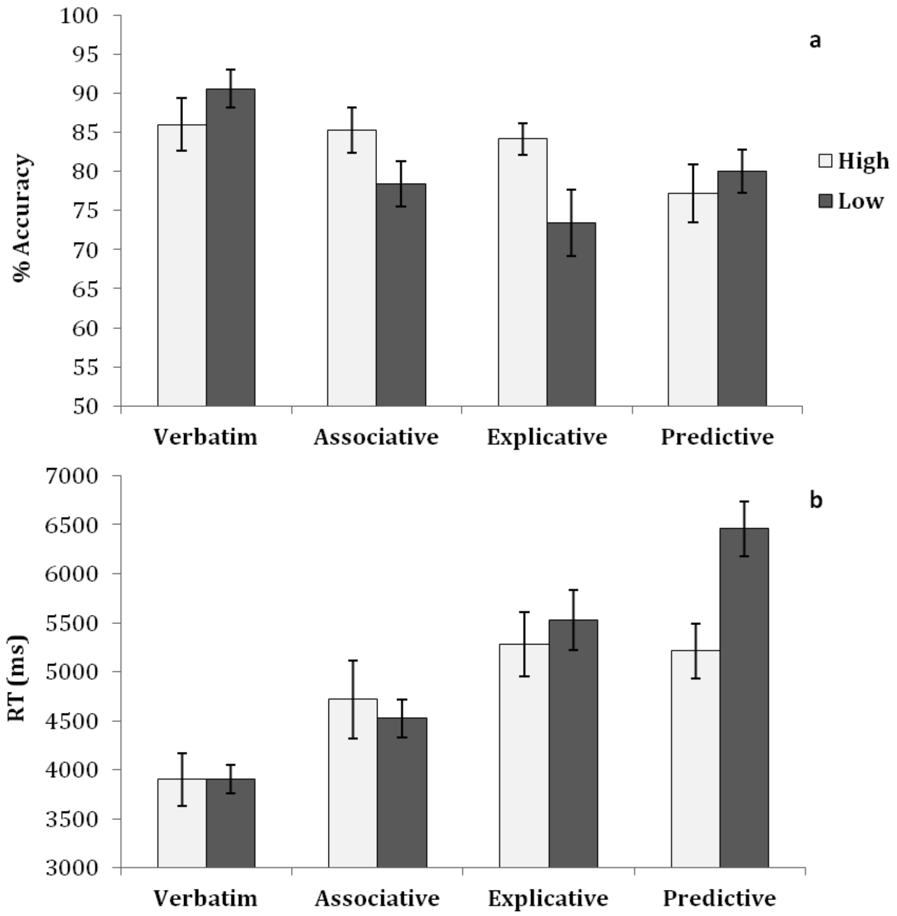

Figure 5. Percentage of correct responses (accuracy; panel a) and response latency (in milliseconds; panel b) of the four comprehension sentences.

Although participants were categorized in terms of their verbal working memory capacity, within group variability allowed us to treat working memory as a continuous variable and perform correlational analyses regarding the relation between working memory span and both performance measures. Furthermore, in order to evaluate if working memory capacity operated as a continuous variable we performed correlational analyses between span scores and both performance measures. When participants responded to comprehension sentences involving explicative inferences, we observed a positive correlation between working memory span and accuracy ($r = .35$, $p < .05$). However, the correlation between working memory span and accuracy was not significant when participants responded to sentences involving verbatim information ($r = -.19$); associative inferences ($r = .20$) or predictive inferences ($r = -.16$; all *ps* > .05). In addition, response latency was negatively correlated with working memory span when participants responded to sentences involving predictive inferences ($r = -.42$, $p < .01$). However, the correlation between working memory span and comprehension sentences involving verbatim information ($r = .03$), associative inferences ($r = .17$) or explicative inferences ($r = -.04$) were not significant (all *p*s > .05).

3.1.4. Discussion

The aim of this study was to evaluate whether responses to comprehension sentences involving different types of inferences in relation to a text, depended on the participants' working memory span. Overall, we observed that comprehension sentences requiring verbatim information were easier (higher percentage of correct responses) and faster (shorter latency) than those demanding inference making (associative, explicative and predictive inferences). However, more important was the observation that the results of the comprehension task were modulated by the participants' working memory span. Low verbal working memory participants showed a smaller number of correct responses to comprehension sentences involving explanations and they took longer to identify predictions relative to high verbal working memory participants. Nevertheless, low and high working memory participants did not differ when they responded to comprehension sentences that involved associative inferences. Moreover, the correlational analyses were consistent with these results: 1) the percentage of correct responses in the explicative inferential sentences increased as the participants' working memory span increased; and 2) the response latency to the predictive inferential sentences was faster when the participants' working memory span increased.

The pattern of results obtained in the current study is in line with previous literature that relates verbal working memory capacity to inference generation. Some studies have shown a relationship between working memory and the generation of bridging and explicative inferences (e.g., Barreyro, Cevasco, Burín, & Marotto, 2012; Friedman & Miyake, 2000; Singer, Andruslak, Reisdorf, & Black, 1992). For example, Singer et al. (1992) found that high verbal working memory readers were more accurate at retrieving connective inferences than low verbal working memory readers when sentences providing inferential information were very distant in the text. In addition, previous research on predictive inferences has shown faster reading times for high relative to low verbal working memory participants in high causal constraint context (e.g., Linderholm, 2002; see also Virtue, Parrish, & Jung–Beeman, 2008). Finally, there are also studies showing a lack of working memory differences in the generation of associative inferences or even better performance of low working memory participants. For instance, using a lexical decision task to evaluate instrumental inferences, Hagaman (2008) found that participants with low working memory span generated more instrumental inferences than participants with high span. The author suggested that both high and low working memory span readers activated the same number of inferences, but that high working memory participants have better attentional control which prevents the intrusion of irrelevant information into working memory.

As we already mentioned, in order to provide coherence to the situation model, readers generate multiple inferences that dynamically integrate their prior knowledge with text information. In this sense, the paradigm used in the current study seems to be useful to evaluate the responses to comprehension sentences that involved verbatim information and inference making. In agreement with previous studies, it might be possible that readers generated the explicative and predictive inferences on–line during the reading of each paragraph (e.g., Beeman et al., 2000; Calvo et al., 2006), and the associative inferences off–line when they answer to comprehension sentences (e.g., McKoon & Ratcliff, 1992). However, since participants responded to comprehension sentences at the end of each paragraph, it is difficult to determine the moment in which participants produced the inferences (see Potts, Keenan, & Golding, 1988). Nevertheless, responses to comprehension sentences required the maintenance of information as the paragraph was not available when the sentences were presented to the participants. Hence, it is reasonable to assume that the differences found between sentences involving verbatim information and those requiring inference making was due to additional processes associated with inference generation. In other words, while sentences involving verbatim information required the maintenance of information from the text, inference making might require additional processes to connect information presented in the text with the retrieval of information from long–term memory. Neuropsychological data support the distinction between verbatim and inferential processing. For example, it has been observed that the establishment of coherence and inference generation differentially recruit the dorsomedial prefrontal cortex, posterior cingulated cortex and middle temporal gyrus (Kim, Yoon, Kim, Lee, & Kang, 2012), illustrating the need to recruit different brain areas in order to generate information that has not been made explicit in the text. However, the relation between working memory span and inference making was not observed in all types of comprehension sentences but only in those requiring explicative and predictive inferential information. Hence answered pending question is why these inferences were associated with working memory span while associative inferences were not. The answer to this question might be related to specific underlying processes involved in explicative and predictive inferences. Explicative inferences demanded information about 'why' something happened in relation to a specific causal antecedent, and predictive inferences required determining if something was going to happen in relation to a concrete causal consequent. In this sense, both explicative and predictive inferential sentences are based on the connections that readers establish between the causal referent and other sentences of the text, which in turn depends on working memory (e.g., Calvo et al., 2006; van den Broek, 1990). In contrast, associative inferential sentences were not explained by causal relationships but by more specific information of the story's circumstances (e.g., the state of a character, the physical place, as well as the historical context), which is mainly based on the retrieval of the readers' background knowledge, stored in long–term memory (e.g., Trabasso & Magliano, 1996). Consequently, working memory differences found between explicative and predictive comprehension sentences may be explained by the need to maintain critical contents in the verbal domain of working memory and to establish causal relationships between them, which is not required for associative sentences (e.g., Virtue et al., 2006). Participants with poor verbal working memory may have problems maintaining information about the causal referent and therefore, failed to correctly answer sentences entailing explanations and thus took more time to answer sentences requiring predictions. Alternatively, participants with high working memory span could benefit from their verbal capacity to maintain a larger amount of causal information and to make connections, leading them to accurately answer more sentences involving explicative inferences and to rapidly answer sentences involving predictive sentences.

The relation between explicative inferences and verbal working memory contrast with previous studies failing to observe a relationship between the reading span task and a situation model task based on inference making (Radvansky & Copeland, 2004). However, the differences between studies might be accounted for the type of inference required to comprehend the text. Radvansky and Copeland evaluated inferences that were in part explanation–based (e.g., reading that '*The driver had just pulled into a gas station*' participants had to infer that '*The gas tank of the car was nearly empty*'). However, these inferences might be closely related to associative information (e.g., the context of 'gas station' might easily activate the idea of 'gas need' in long–term memory) which would favour the inference making process even in low working memory span readers. Additionally, due to the high correlation between working memory and other abilities (such as intelligence quotient), we cannot discard the relative contribution of other factors in our results. It would be interesting to assess this issue in future research.

Although we have observed that verbal working memory modulated responses to comprehension sentences involving explicative and predictive inferences, we are not defending that the processes underlying these two types of inferences are the same. A possible difference between explicative and predictive inferences might be similar to the distinction between the remembering of episodic memories and episodic future thinking [5]. Several studies have

[5] We thank G.A. Radvansky for recommending the literature on episodic future thinking and suggesting the possible difference between explanations and predictions.

demonstrated that the imagining of future events draws on the same structures as the remembering of episodic memories (e.g., Schacter, Addis, & Buckner, 2007). Nevertheless, more than simply retrieve information from memory, the ability to foresee future events also requires the recombination of stored information into a novel event, which additionally activates the hipocampal region (e.g., Schacter & Addis, 2007). Similarly, explanations and predictions require the maintenance of a large amount of text information in verbal working memory. However, explanations might involve the connection of information presented in the text with the readers' knowledge stored in long–term memory, while predictive inferences might require an additional process of generating possible future events.

To sum up, this is the first study demonstrating that the role of verbal working memory in sentence comprehension varies depending on the three types of inferences specified by Trabasso and Magliano (1996). The relation between working memory and comprehension sentences obtained in this study might indicate different cognitive processes underlining explicative, predictive and associative inferential sentences. Concretely, we suggest that both explicative and predictive sentences are mainly based on the maintenance of prior parts of the text in the verbal domain of working memory since they require the establishment of casual relationships across the story. On the contrary, associative sentences do not depend on verbal working memory, since they are basically generated by the activation of prior knowledge which relies on long–term memory.

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STUDY 2

Monitoring and Updating of Inferential Comprehension in Narrative texts: an Eye Movement study

Pérez, A., Joseph, H., Bajo, T., & Nation, K. (submitted). Monitoring and updating inferential comprehension in narrative texts: an eye movement study. *Scientific Studies of Reading*.

Abstract

We investigated the processes of monitoring and updating inferential information in adults' reading comprehension by monitoring their eye movements as they read both narrative texts and critical sentences. In the narrative text, a short introduction primed a specific interpretation, followed by the introduction of a concept that was either expected (e.g., '*chess*') or unexpected (e.g., '*snap*') in relation to the inferred interpretation. Readers detected the inconsistency between the new unexpected information and their prior interpretation, confirming their ability to monitor inferential information. Below the narrative text, a critical sentence included target words that were congruent (e.g., '*moving pieces*') or incongruent (e.g., '*playing cards*') with the expected but not the unexpected concept. Readers spent less time reading the congruent than the incongruent target words, reflecting the facilitation of prior information. More specifically, lower verbal (but not visuospatial) span readers failed to suppress their initial incorrect interpretation, resulting in more rereading of the text to update the information. Higher verbal span readers were more efficient in discarding the no longer relevant interpretation and updating their situation model.

Keywords: reading comprehension; inferential monitoring; updating information; verbal working memory; eye movements; linear mixed models.

3.2.1. Introduction

In order to comprehend a text, readers integrate the relevant information in the passage with prior knowledge, building up a coherent and accurate mental representation of the text typically known as a situation model (Kintsch & van Dijk, 1978). The construction of a situation model entails the involvement of distinct high–level cognitive processes such as inference making (e.g., Cain & Oakhill, 1999), comprehension monitoring (e.g., Bohn–Gettler, Rapp, van den Broek, Kendeou, & White, 2011), and/or updating information (e.g., Rapp & Kendeou, 2007).

Comprehension monitoring refers to the metacognitive processes by which comprehenders supervise and evaluate their own understanding of a text. According to Wagoner (1983), '*it is an executive function, essential for competent reading, which directs the reader's cognitive processes as he/she strives to make sense of incoming textual information.*' Therefore, the ability to monitor comprehension is essential to track new information presented in a text as well as any changes that force a restructuring of the situation model. The classic paradigm to study comprehension monitoring has been the contradiction or inconsistency detection task (e.g., Albrecht & O'Brien, 1993; Huitema, Dopkins, Klin, Myers, 1993; O'Brien, Rizella, Albrech, & Halleran, 1998; Orrantia, Múñez & Tarín, 2013). In this paradigm readers are presented with information regarding a specific character followed by an action that the character performs that may be consistent or inconsistent with the previous information. The typical effect is a time cost in the inconsistent compared to the consistent sentence, suggesting an increase in information processing when the coherence of the situation model is disrupted.

Interestingly, comprehension monitoring can be linked to inference making. Inference making is one of the most fascinating and indispensable abilities in reading comprehension. Its main function is to provide coherence by joining together text information with a reader's prior knowledge. Thus, beyond all taxonomies and names that have been proposed (see Graesser, Singer, & Trabasso, 1994; and also Graesser & Zwaan, 1995 for review), inferences are the principal engine to establish consistency in text processing. Consequently, if the reader encounters information that is inconsistent with any inferred concept, there should be a cost to the ease of the reading process. Evidence consistent with this comes from a study using the contradiction paradigm while measuring readers' eye movements. Poynor and Morris (2003, Experiment 2) presented a character's goal that was explicit (e.g., '*[Dick] wanted to go somewhere warm and sunny*') or implicit (e.g., '*[Dick] had always been a real sun–worshipper*'), followed by an action that was consistent (e.g., '*[He]... asked for a plane ticket to Florida*') or inconsistent (e.g., *[He]... asked for a plane ticket to Alaska*') with the character's goal. They found longer reading times (first–and second pass times) in the inconsistent than in the consistent condition regardless of whether the goal had been explicitly or implicitly stated in the text, and more frequent rereading (regressions in) of the goal information in the inconsistent condition when the goal has been explicitly mentioned. In addition, Poynor and Morris (2003, Experiment 1) also evaluated the recall of the passages using an off–line recall test and they found better recall (for both goal and action) in the inconsistent than in the consistent passages. The better recall of the inconsistent passages was interpreted as 1) the successful reinstatement of the prior unsatisfied goal (explicit: '*somewhere warm and sunny*', or implicit: '*a real sun–worshipper*') and its integration into the memory representation, and 2) the strengthening of the inconsistent information because the reinstatement of the prior goal drew attention to the relationship between the goal and the action. From our point of view, these findings are interesting since they indicate readers' ability to monitor inferential information. However, there are several reasons why it is difficult to state that the new information was incorporated into the mental representation at the moment of the action. First, longer reading times in the inconsistent information per se do not necessarily reflect integration, but a disruption in comprehension because incoming information does not fit with the current representation. Second, immediately after reading each passage, readers were presented with a comprehension question (e.g., '*Did Dick originally plan to go to a cold climate?*') that was focused on the resolution of the inconsistency. Arguably, this might bias the subsequent recall. Finally, readers with more than 15% of incorrect responses to the comprehension questions (14% of participants) were excluded from the analysis of the recall data, and no explanation was provided for such a noticeable amount of incorrect responses. Hence, although these results support the hypothesis that comprehension monitoring includes the monitoring of information not explicitly present in the text, it is not clear if readers integrate the new inconsistent information into their situation model while reading.

In addition to monitoring, when readers detect an inconsistency between text information and their inferred mental representation, they are forced to revise the current memory representation, replacing it with the newly uncovered information. This process is known as updating and has been extensively studied in connection with situation models (e.g., Albrech & O'Brien, 1993; O'Brien, et al., 1998; Rapp & Kendeou, 2007; de Vega, 1995; Zwaan & Madden, 2004; Radvansky & Copeland, 2010). Accordingly, it has been observed that readers commonly experience difficulty in updating the new contradictory information, because the prior encoded information continues to interfere with comprehension (e.g., Guèraud, Harmon, & Peracchi, 2005; O'Brien et al., 1998; van Oostendorp & Bonnebakker, 1999). Several models of comprehension have tried to provide an explanation of why this occurs. For example, the Structure–Building model (Gernsbacher, 1990, 1997) proposes that when inconsistent information cannot be integrated into the mental representation, readers try to suppress the information that is not longer relevant. However, when readers are unable to suppress the irrelevant information, they may form new substructures constructed out of the main mental representation. After several substructures are established, the accessibility of information in memory is reduced and readers thus fail to update their situation model (e.g., Gernsbacher & Faust, 1991; Gernsbacher, Varner & Faust, 1990). Therefore, monitoring and updating are closely related processes that are critical for comprehension. However, very few studies have studied their interrelation (e.g., van der Schoot, Reijnties, van Lieshout, 2012). In addition, studies investigating the updating of situation model have usually used a sentence–by–sentence procedure and thus, they have only evaluated reading times and/or comprehension questions in an off–line way (e.g., Albrecht & O'Brien, 1993; Rapp & Kendeou, 2007; O'Brien et al., 1998; Zwaan & Madden, 2004). Since monitoring and updating should occur on–line as the arguments in text unfold, it is important to use on–line measures to capture the interrelation between these processes. Therefore, the first goal of the present work was to study the cognitive processes of comprehension monitoring and updating information during on–line reading.

Monitoring eye movements is an ecologically valid technique to study reading comprehension since 1) it allows the reader to read text at their own pace without the need for any secondary task; 2) it provides information about the time course of text processing on–line, as reading happens; and 3) it also provides information about reading behavior during and after reading of a comprehension question. For these reasons, we used eye movements to measure inferential monitoring and updating of a situation model on–line, as participants read text. Specifically, we presented a prior context which primed an inferential concept and subsequent explicit information that either confirmed or disconfirmed the inferred concept. This provided a manipulation of inferential monitoring. In addition, below the main text a critical sentence was presented that was either congruent or incongruent with the explicit concept introduced in the main text. This sentence allowed us to examine if readers had incorporated the new concept into their situation model. Eye movements were recorded as participants read both the main text and the subsequent critical sentence.

An additional goal of the present study was to explore the role of working memory in monitoring and updating. The findings that some people show a significantly more number of incorrect responses after monitoring inconsistencies (Poynor & Morris, 2003) and that poor skilled readers reflect poor suppression of irrelevant information (e.g., Gernsbacher & Faust, 1991) suggest that there are individual differences in the way that readers update information. Consequently, we also aimed to explore if individual differences in working memory capacity are associated with this process.

Working memory capacity has been related to high–level language skills such as listening or reading comprehension (e.g., Daneman & Merikle, 1996). The relationship between reading comprehension and working memory has been typically found in complex span measures such as the reading and listening span tasks (Daneman & Carpenter, 1980), where readers are required to recall verbal information (e.g., digits or words), while completing an additional task (e.g., comprehending sentences). In general, these studies conclude that readers with low working memory capacity are less able to maintain and process text information, having difficulties integrating it with prior knowledge into a coherent situation model (e.g., Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Hannon & Daneman, 2001). Subsequent studies have demonstrated the influence that working memory exerts in high–level processes such as inference making (e.g., George, Mannes, & Hoffman, 1997; Virtue, van den Broek, & Linderholm, 2006). In relation to comprehension monitoring, although several studies have found a relationship between working memory and the ability to detect inconsistencies in children (e.g., Cain, Oakhill, & Bryant, 2004; Oakhill, Hartt & Samols, 2005), young adults seem to be able to successfully detect inconsistencies irrespective of working memory capacity (e.g., Bohn–Gettler, et al., 2011; De Beni, Borella, & Carretti, 2007). Furthermore, it is still unclear whether the process of updating information into the situation model depends on working memory, and if so, if it is a domain–specific mechanism. Individual differences in reading comprehension are more closely associated with verbal working memory (Carretti, Borella, Cornoldi, & De Beni, 2009; Nation, Adams, Bowyer–Crane, & Snowling, 1999; Pimperton & Nation, 2010; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000). Therefore, an additional goal of this study was to investigate if updating was specifically associated with verbal and not visuospatial working memory differences.

The current study

We recorded eye movements during natural reading to investigate how readers monitor and update their inferential comprehension. Our paradigm was as follows (see Table 2; see Appendix C for full materials, p. 197). A brief introduction of two–sentences (e.g., '*...the last two players were concentrating hard at each end of the table... taking a long time to make a decision*') primed a specific concept at the situation model level. The third sentence introduced a target concept that could be expected (e.g., '*chess*') or unexpected (e.g., '*snap*') according to the prior information. Just below, a critical sentence contained target words that could be congruent (e.g., '*moving pieces*') with the expected but not with the unexpected concept, or incongruent (e.g., '*playing cards*') with the expected but not with the unexpected concept.

Table 2. Example of a text used in the inferential monitoring task.

At the end of the tournament, the last two players were concentrating hard at each end of the table. Both of them were taking a long time to make a decision. After an hour and a half the *chess/snap* game was finished.	**Text**
- The players were *moving pieces* to win the tournament. - The players were *playing cards* to win the tournament.	**Sentence**

Note. Participants read either the expected ('*chess*') or unexpected ('*snap*') concept in the main text, and the congruent or incongruent words with the prior concept in the critical sentence.

Our general proposal is that if readers properly generate the inference as they read the first two sentences, they will exhibit longer reading times on the unexpected concept (e.g., '*snap*') than expected concept (e.g., '*chess*') and/or more regressions out of this concept to previous parts of the text. This result would reflect their ability to monitor information that does not fit with the prior inferred situation model. Subsequently, when reading the critical sentence, if only expected information has been encountered, readers should benefit from their already activated memory representation (e.g., '*chess*') showing shorter reading times, and/or fewer regressions out of the congruent (e.g., '*moving pieces*') compared to the incongruent (e.g., '*playing cards*') target words . This effect would reflect a general ability to construct a coherent situation model, since no change has occurred in the story. Correspondingly, the target words of the critical sentence will require longer reading times and/or a larger number of regressions when the unexpected concept is congruent (e.g., '*playing cards*' after '*snap*') than when the expected concept is congruent (e.g., '*moving pieces*' after '*chess*'). This processing cost would point to the need to suppress the concept introduced at the beginning of the text, updating the new unexpected concept into the situation model.

We also examined whether the effect of inferential monitoring and updating processes were related to readers' verbal (measured by the listening recall and backward digits recall tasks) and/or visuospatial (measured by the odd one out and spatial recall tasks) working memory capacity. Because young adults often monitor inconsistencies during normal reading (e.g., Bohn–Gettler, et al., 2011; De Beni, et al., 2007), and the inconsistency was very evident in the text, we predicted no working memory differences in the inferential monitoring process. In contrast, we predicted more efficiency in the updating of higher compared to lower verbal span readers, with few or no influence of the visuospatial domain. Specifically, we expected higher verbal span readers to exhibit shorter reading times and/or fewer regressions than lower verbal span readers on the target words in the critical sentence. Finally, regarding accuracy, if the presentation of the unexpected concept exerts an influence on the product of comprehension, we should find a smaller number of correct responses to the critical sentence when the unexpected compared to the expected concept has been presented. Working memory differences were not predicted in accuracy, because readers had the opportunity to check text information before answering to the critical sentence. To our knowledge, this is the first study assessing the process of updating the situation model during on–line reading. To do this, we measured eye–movements during reading of both the main text and the critical sentence. In addition, we wanted to see whether updating process was associated with verbal and not visuospatial working memory differences.

3.2.2. Method

Participants

Forty people (mostly undergraduates but also postgraduate students) with a mean age of 21.9 years old (range: 17–47 years)[6] were recruited by an internet advertisement placed in the webpage of the University of Oxford (UK). All were native English speakers with no known reading disabilities and normal or corrected to normal vision. They participated for either course credits or money (£10).

[6] Most of participants had an age close to 20 years old. Only two participants differed from the mean group of age (32 and 47 years old), which explains the large age range.

Materials

The proper experiment was the inferential monitoring task, where eye movements were measured as participants read a main text and a critical sentence. In addition, participants completed four working memory span tasks in the verbal and visuospatial domains.

Inferential monitoring task. We constructed 34 (4 practice, 30 experimental) four–sentence narrative texts (see Table 2). The first two sentences biased an inference generated at the situation model of the story. The third sentence presented one of two conditions: a) in the expected condition appeared the concept primed by the introduction (e.g., '*After an hour and a half the chess game was finished*'), which was consistent with the previous information; b) in the unexpected condition was presented a valid but unlikely concept (e.g., '*After an hour and a half the snap game was finished*'), which was inconsistent with the previous information and forced participants to change their mental representation. A preliminary pilot study was carried out in order to test the two target concepts (e.g., *chess*/*snap*). Participants read each text in one of the two versions of the third sentence. They were instructed to mark from 1 (worst) to 5 (best) how well one of the two target concepts fitted with the ideas in the text. Seven participants completed each version of each text. In the final study, only texts for which the expected condition (M = 4.23) had a better fitting than the unexpected condition (M = 2.21) were included. A t–test comparison confirmed the difference, $t(29) = 15.80$, $p < .001$. Then, the word frequency of the two target concepts was matched using the SUBTLEX database (Brysbaert & New, 2009): M expected = 34.73; M unexpected = 36.24, $t(30) = 0.14$, $p = .89$. In addition, the number of characters of each word was also controlled between conditions, Ms = 5.58, and 5.65 for the expected and unexpected concepts respectively: $t(30) = 0.30$, $p = .76$. Only an empty line (gap) separated the main text from the critical sentence presented below, which were presented at the same time. Participants were instructed not to read the critical sentence before they had read the main text. This sentence presented one of two possibilities: a) in the congruent condition the information was related to the target concept read in the target concept read in the main text (e.g., after reading '*snap*' , they encountered '*The players were playing*

<u>*cards*</u> *to win the tournament*' as the critical sentence); or b) in the incongruent condition the information was always unrelated to the target concept read in the main text (e.g., after '*snap*', they encountered '*The players were* <u>*moving pieces*</u> *to win the tournament*' as the critical sentence). Participants were instructed to press one of two buttons to answer '*Yes*', if they thought the critical sentence was correct, or '*No*' if they thought it was incorrect. Once more, we used SUBTLEX to control the word frequency of the target words (e.g., *playing cards/moving pieces*) presented in the comprehension sentence: *M* congruent = 256.17; *M* incongruent = 437.13, $t(44) = 1.52$, $p = .14$. The number of characters did not differ between conditions, *Ms* = 5.78, and 5.96 for the congruent and incongruent target words respectively: $t(44) = 0.69$, $p = .50$.

Working memory measures

Working memory capacity was measured by standardized Automated Working Memory Assessment battery (AWMA; Alloway, 2007). Four span tasks were used: two verbal and two visuospatial. Each task was administered according to the manual instructions with difficulty increasing progressively over blocks by the number of items to be remembered. Participants continued with the next block if they recalled 4 out of the 6 trials. In contrast, when participants failed at least 3 trials of the same block, the task finished. The scores of each working memory task were the total number of trials correctly recall. Errors were not included in the final score.

(i) *Listening recall*. Participants listened to sets of spoken sentences presented one by one and were instructed to verify if each sentence was 'true' or 'false'. In addition, at the end of each set of sentences, they were required to recall the last word of each sentence in the order of presentation.

(ii) *Backward digits recall*. Immediately after the presentation of a spoken list of digits, participants had to recall the sequence in the reverse order. There were six levels increasing in difficulty from 2 (Level 1) to 7 (Level 6) digits.

(iii) *Odd one out*. Participants were presented with a three square matrix containing a shape in each space, and they had to point at the figure that was different to the other two. At the end of each set, participants were also required to indicate on the screen the location of each shape in order of presentation.

(iv) *Spatial recall*. Two shapes were presented at the same time. The shape of the right side could be rotated and contained a red dot that changed position (over three compass points). Participants must judge if both shapes were the 'same' when they followed the same direction or 'opposite' when they had a different direction. At the end of the set, a figure with the three compass points appeared on the screen and participants had to recall the location of the dot in order of presentation.

Since we were more interested in the working memory domain rather than in the specific tasks, we used two composite scores distinguishing between the verbal domain (including the listening recall and backward digits recall) and the visuospatial domain, (including the odd one out and spatial recall). These scores were extracted from the AWMA battery.

Apparatus

Participants' eye movements were monitored using an Eyelink 1000 (SR Research; Mississauga, Canada) eye–tracker. The sampling rate was 1000 Hz. A chinrest and forehead rest were used to minimise head movements and to maintain a constant viewing distance of approximately 60 cm. Viewing was binocular but only the right eye was tracked during the experiment. A nine–point calibration procedure was performed to ensure that tracking accuracy was within 1º of visual angle. Re–calibration was carried out between trials as needed. The stimuli were presented on a 19" CRT video monitor (refresh rate = 75 Hz), using the Eyetrack software[2], and the extraction of eye movements measures were carried out using EyeDoctor and EyeDry[7]. The eye movements were: *gaze duration*, is the total duration of all fixations in a region before leaving it from left or right

[7] Taken from http://www.psych.umass.edu/eyelab/software/

side; *regressions out*, is the probability of making a leftward eye movement from a region to read previously encountered text; *go–past time*, refers to the sum of all fixations from the first entering a region from the left to exiting it from the right, including re–reading of previous parts of the text; *regressions in*, is the probability of making a leftward eye movement into a specific region; and *total time*, is the total duration of all fixations in a region, including first and second–past times. The administration of the working memory tasks (AWMA program) was via a 15" laptop computer screen.

Procedure

The eye movement experiment (inferential monitoring task) was first and took approximately 30 minutes. Participants triggered the onset of each trial by fixating a box on the left of the screen. Both the main text and the critical sentence appeared and readers read at their own pace, starting with the text. The information disappeared from the screen when participants pressed the designated true or false key to respond to the critical sentence. Each of 30 experimental trials was presented to each participant only once in one of the four cross conditions (expected–congruent, unexpected–congruent, expected–incongruent, or unexpected–incongruent) counterbalanced across participants. The same number of participants completed each condition, and the presentation of trials was randomized. Four practice trials presented at the beginning of the experiment ensured that instructions were understood, and a small break (about 1 min.) halfway through the task prevented fatigue. Following the experiment, the four working memory tasks were presented in the following order: listening recall, backward digits span, odd one out and spatial recall. In all of them instructions appeared as a sound file with a blank screen, followed by the practice trials. In the experimental trials, responses were recorded discreetly by the experimenter using the right arrow key on the keyboard (⇨) for a correct response and the left arrow key (⇦) for an incorrect response.

Data analysis

We constructed linear mixed models using the lmer function of the lme4 R package, version 1.0–5 (Bates, Maechler, Bolker, & Walker, 2013). These models are very powerful since they account for both fixed and random effects, allowing the analysis of participant and item at the same time. Separate models were run for each dependent variable (gaze duration, regressions out, go–past time, regressions in and total time) across both regions of our inferential monitoring task (main text and critical sentence). All data were checked to ensure that no participant read the critical sentence before the main text. In addition, accuracy of response to the critical sentence was also analyzed. Participants and items were the random factors of the model.

Expectation (expected vs unexpected) and Congruence (congruent vs incongruent) were always fixed factors. In addition, one of the two domains of working memory was also included as a fixed factor: Verbal working memory, M = 85.07 (SD = 11.23; range = 72–114; or Visuospatial working memory, M = 84.75 (SD = 11.29; range = 66–111. To improve interpretability, the verbal or visuospatial factors were centred in order to understand the average (or intercept) of each factor (e.g., Schielzeth, 2010). Thus, in both cases, the fixed structure was composed by a three–way interaction (e.g., expectation x congruence x verbal working memory). In order to establish the optimal structure for the random and fixed components, we followed a well–known procedure in the field of ecology (see Zuur, Ieno, Walker, Saveliev, & Smith, 2009). First, keeping the full fixed structure, we looked for the best random structure using restricted maximum likelihood (REML). We assumed different random intercepts since both of them could have a different baseline, and we found the justified–by–the–design optimal random slopes using model comparison (see Appendix D, p. 203; see also Barr, Levy, Scheepers, & Tily, 2013 for a review). Second, keeping the already known random structure, we found the best fixed structure using stepwise model comparison from the most complex model (the three–way interaction) to the simplest (a main effect) model, and selecting the one with lower AIC and BIC, and significant χ^2 test for the Log–likelihood, using the maximum likelihood (ML). Finally, for those models with significant fixed effects, the p values were provided by the anova function of the lmerTest R package, version 2.0–3 (Kuznetsova, Brockhoff, Christensen, 2012), using the REML. To assess the overall goodness of fit we calculated the explained deviance by the pamer.fnc function of the LMERConvenienceFunctions R package, version 2.5 (Tremblay & Ransijn, 2013). This statistic lies between 0 and 1 and serves as a generalization of R^2 since it measures the marginal improvement or reduction in unexplained variability in the fixed component after accounting for a given predictor effect. In the case that post–hoc comparisons were necessary, we used the testInteractions function of the phia R package, version 0.1–5 (de Rosario–Martínez, 2012).

3.2.3. Results and discussion

Our results are organised into four sections. Each section assesses a specific theoretical hypothesis and provides a short interpretation of the key findings. We first examined the target concepts of the main text, addressing whether readers generate the critical inference in the introductory sentences and monitor their comprehension by the detection of unexpected information. Second, we analysed the target words of the critical sentence, considering whether readers have updated the concept of the text establishing a coherent situation model. Third, in relation to individual differences in working memory, we analysed two regions 1) the target concept of the main text, where no working memory differences were expected in the detection of the unexpected information; and 2) the target words of the critical sentence, where working memory differences should be associated with updating of the unexpected concept. Additionally we observed whether these differences are related to specific verbal capacity or to more general capacities including visuospatial working memory. Finally, we analysed readers' accuracy, explaining whether the product of comprehension depends on comprehension monitoring.

Taking into account the large number of results presented in this study, we focused on the significant fixed effects of each linear mixed model, and only reported the factors comprising the random structure. The summary details (lmerTest package) of each model are provided in Appendix E (p. 205).

Did readers monitor inferentially unexpected information?

To investigate if readers generated an inference in the introductory sentences and thus, were able to detect the inferentially unexpected information, we ran linear mixed models on the target concepts of the text region (e.g., *chess*/*snap*) for all gaze duration, regressions out, go–past time, regressions in and total time eye movement measures.

The linear mixed models performed on go–past time (Model 1), the number of regressions into the target words (Model 2), and total time (Model 3) demonstrated a main effect of expectation, with longer go–past times, $F(1) = 5.43$, $p = .02$, $dv = .60$, larger number of regressions, $F(1) = 4.15$, $p = .05$, $dv = 0.46$, and longer total times, $F(1) = 6.38$, $p = .02$, $dv = .63$, in the unexpected than in the expected condition (see Table 3a, 3b, and 3c). In addition, the random structure of the regression in and total time measures manifested the random slope of expectation for the item factor. This meant that the items varied within the expectation variable, and its effect was controlled with its inclusion in the model. No other random or fixed effect was significant in any of the three models, and not other eye movement measure was significant in this region.

Therefore, once the text information biased a context, readers were able to infer the target concept and incorporate it into their mental representation. Moreover, the cost associated with processing the unexpected relative to the expected concept, confirmed readers' ability to monitor their comprehension by the detection of information that did not fit with their prior inferred concept.

Did readers update the unexpected information into their situation model?

In order to understand if readers updated the target concepts of the text into a coherent situation model, we carried out linear mixed models on the target words of the critical sentence region (e.g., *moving pieces*/*playing cards*), once more for all eye movement measures.

The linear mixed model performed on total time (Model 4) reflected a significant main effect of congruence, $F(1) = 4.53$, $p = .04$, $dv = 0.25$, with longer total times on the target words of the incongruent than in the congruent condition; and a significant two–way interaction of expectation x congruence, $F(2) = 5.68$, $p = .003$, $dv = 0.62$ (see Table 3d). Post–hoc comparisons with Bonferroni correction on the two–way interaction showed that readers spent significantly less time reading the congruent than the incongruent target words only when they had previously seen the expected concept, χ^2 (1) = 14.19, $p < .001$, not when they have seen the unexpected concept, χ^2 (1) = 0.25, $p = 1.00$, in the main text. Additionally, readers took significantly longer to read the target words in congruent critical sentences, χ^2 (1) = 7.48, $p = .01$, when the main text had presented the unexpected concept, compared to the expected concept. In contrast, this effect was not significant for the target words encountered in incongruent critical sentences, χ^2 (1) = 3.90, $p = .10$. The random structure produced the random slope of congruence for both participant and item. No other random or fixed effect was significant, in any of the eye movement measures.

Plausibly, at least two different cognitive processes might underlie this interaction. On one hand, after the presentation of the expected concept, the benefit for reading the target words in the congruent relative to the incongruent comprehension sentence, verified that readers had activated the concept in their memory representation. Nevertheless, no benefit effect was found when the unexpected concept was presented, suggesting that besides the unexpected concept, the expected concept was still active in memory. The pattern of means is also consistent with this possibility, since the presentation of the unexpected concept entailed shorter reading times in the critical sentence (in both the congruent and incongruent conditions) than reading the incongruent condition after the presentation of the expected concept. On the other hand, the processing cost that readers showed on the target words of the congruent critical sentence after the unexpected concept compared to the expected concept indicated that readers experienced difficulty discarding the expected concept from their situation model.

Was there any evidence of individual differences in working memory capacity associated with updating the unexpected information?

To address whether individual differences in the way in which readers update their mental representation after the presentation of inconsistent information was associated with differences in working memory, we ran separate linear mixed models for the verbal and visuospatial domain of working memory. We analysed two regions: 1) the target concept of the main text to clarify if there were individual differences in the monitoring process, and 2) the target words of the critical sentence to understand if the updating process was explained by the verbal domain of working memory. Again, we did this for all eye movements measures.

The linear mixed model conducted on the regressions out of the target concept of the main text (Model 5) reflected a main effect of verbal working memory, $F(1) = 4.18$, $p = .05$, $dv = .51$, where readers with higher verbal span made significantly fewer regressions out of the target concepts, than lower verbal span readers (see Table 3e). No other fixed or random effect was significant, in any of the other eye movement measures. Therefore, no model including the visuospatial working memory domain was significant.

The linear mixed models performed on the go–past time (Model 6) and regressions into (Model 7) the target words of the critical sentence, showed a two–way interaction of expectation x verbal working memory: for go–past time, $F(2) = 3.91$, $p = .02$, $dv = 0.57$, higher verbal span readers showed significantly shorter go past times than lower verbal span readers when the target concept was unexpected, $t = -2.75$, $p = .007$, but not when it was expected, $t = 0.04$, $p = .97$, (see Table 3f); for regressions in, $F(2) = 5.44$, $p = .006$, $dv = 0.76$, higher verbal span readers made significantly fewer regressions into the target words of the critical sentence than lower verbal span readers when the target concept was expected, $t = -3.11$, $p = .003$, but not unexpected, $t = -0.59$, $p = .56$ (see Table 3g). In the random structures, the item factor generated the variables of expectation for the go–past time and congruence for the regression in measure. These effects were controlled with the inclusion of their random slopes. No other random or fixed effect was significant in any of the two models, or in any of the other eye movement measures. So again, no model including the visuospatial working memory domain was significant.

According to our results, there was only a main effect of verbal working memory in the monitoring process: higher verbal (but not visuospatial) span readers regressed out of the two target concepts fewer times than lower verbal span readers. Thus, rather than a more specific problem detecting the inconsistency, these differences were associated to a less ability of the lower verbal span readers to integrate the target concept (expected and unexpected) with prior text information. Moreover, individual differences were apparent in the process to update inconsistent information. First, readers with higher verbal span showed shorter go–past times than lower verbal span readers but only when the unexpected concept has been presented. This suggests that higher verbal span readers did not require rereading the main text to discard the expected concept primed in the introduction. In contrast, lower verbal span readers spent more time rereading the main text, probably to discard the expected interpretation. Second, readers with higher verbal span made a smaller number of regressions into the target words of the critical sentence than lower verbal span readers, when the expected concept has been previously presented. This indicated that higher verbal span readers had better integrated the expected information when reading the critical sentence than lower span readers.

Did the unexpected information affect the product of comprehension?

Finally, to examine whether the presentation of information that did not fit with the context of the story resulted in problems of comprehension, we performed a linear mixed model on the number of correct responses (accuracy) answering critical sentences. This (Model 8) manifested a main effect of expectation, $F(1) = 15.62$, $p < .001$, $dv = 0.89$, with a smaller number of correct responses in the unexpected than the expected condition (see Table 3h). In addition, a complex random structure was generated and controlled, with the random slope of expectation for the participant factor and an interaction between expectation and congruence for the item factor. No other random or fixed effect was significant.

Therefore, the reduction in the number of correct responses in the unexpected compared to the expected condition indicated that the product of comprehension was affected by the prior inferred concept, despite the fact that the unexpected concept was explicit in the main text. Finally, there were no working memory differences in accuracy, suggesting that lower verbal span readers benefitted from the availability of the story to answer the comprehension sentences.

Table 3. Mean and standard deviation values for each level of the significant fixed effects that resulted in each linear mixed model.

	Measure	Fixed effects	*M*	*SE*
Text	a) *Go-past time*	Expectation:		
		- expected	274	22
		- unexpected	313	39
	b) *Regressions in*	Expectation:		
		- expected	0.11	0.02
		- unexpected	0.16	0.05
	c) *Total time*	Expectation:		
		- expected	268	16
		- unexpected	309	32
Sentence	d) *Total time*	Congruence		
		- congruent	517	63
		- incongruent	570	75
		Expectation:Congruence		
		- expected:congruent	476	49
		- expected:incongruent	600	81
		- unexpected:congruent	557	78
		- unexpected:incongruent	541	69
	e) *Regressions out*	Verbal working memory		
		- verbal working memory*	0.152	0.03
		- higher verbal span	0.149	0.03
	f) *Go-past time*	Expectation:Verbal working memory		
		- expected:verbal working memory*	445	51
		- expected:higher verbal span	445	54
		- unexpected:higher verbal span	438	51
	g) *Regressions in*	Expectation: Verbal working memory		
		- expected:verbal working memory *	0.342	0.04
		- expected:higher verbal span	0.334	0.03
		- unexpected:higher verbal span	0.340	0.03
	h) *Accuracy*	Expectation:		
		- expected	0.87	0.02
		- unexpected	0.67	0.07

* The intercept of the working memory factors represents their average value.

3.2.4. General discussion

The aims of this experiment were to investigate how readers monitor and update inferential information into a coherent situation model. In addition, we evaluated whether working memory was associated with individual differences in updating and whether this was equally so for verbal vs. visuospatial working memory.

In our inferential monitoring task, the first two sentences worked as an introduction that facilitated a concept. The third sentence could be expected, if it contained the concept primed by the introduction (e.g., '*chess*'), or unexpected, if it contained a different concept (e.g., '*snap*') that while possible was nevertheless improbable, given the context established by the two–sentence introduction. In relation to our predictions, our results demonstrated longer reading times (go–past time and total time) and a larger number of regressions (regressions in) in the unexpected compared to the expected target concept of the main text. This cost demonstrated that readers generated the inference in the introduction, and then detected an inconsistency between the unexpected concept and their memory representation. Thus, readers were able to monitor inferential information. These results are consistent with the literature on comprehension monitoring, where a processing cost after encountering inconsistent information indicate that situation coherence has been disrupted (e.g., Albrecht & O'Brien, 1993; O'Brien, et al., 1998; Orrantia, et al., 2013; Poynor & Morris, 2003). In contrast to previous experiments that used texts focusing on a character's goal and subsequent action, our task tapped a wide range of inferences based on reader's world knowledge (e.g., the knowledge that chess is a two–player board game, which requires concentration and frequently a long time to decide on the next move). This distinction could be interesting to theories of comprehension, since it demonstrates that more general knowledge–based inferences are subjected to the process of comprehension monitoring.

After reading the main text, participants read a critical sentence containing either congruent (requiring a '*Yes*' answer) or incongruent ('*No*' answer) target words with the expected or unexpected concepts. In general, readers took less time (total time) to read the congruent than the incongruent target words of the critical sentence, demonstrating facilitation when the information was coherent with the prior concept. More specifically, as hypothesized, the presentation of the expected concept (e.g., '*chess*') resulted in shorter reading times (total time) when reading congruent target words (e.g., '*moving pieces*') compared to incongruent words (e.g., '*playing cards*') in the critical sentence. Since no change had occurred with the expected concept, this result indicated that readers benefitted from the already activated memory representation and thus were able to construct a coherent situation model of the story. Consistent with this, reading times (total time) were longer for target words in critical sentences that were congruent with the unexpected concept (e.g., '*playing cards*' after '*snap*'), than with the expected concept (e.g., '*moving pieces*' after '*chess*'). This time the cost suggested a difficulty in updating the situation model because the prior incorrect interpretation was still active in memory. This result is consistent with those studies demonstrating that the presentation of new contradictory information can lead to difficulties with updating because the prior encoded information continues to interfere with comprehension (e.g., Guèraud, et al., 2005; O'Brien et al., 1998; Oostendorp & Bonnebakker, 1999). Moreover, it is also consistent with the Structure–Building model (Gernsbacher, 1990, 1997), which argues that readers experience problems in integrating the mental representation because they are unable to suppress no longer relevant information. Importantly, the information to be suppressed in our task was inferential (e.g., idea of chess), which could complicate the removal of that elaborated interpretation.

A second aim of our study was to explore the association between inferential monitoring and working memory. Since previous results suggest that unlike children, adults successfully monitor their comprehension (Bohn–Gettler, et al., 2011) we did not predict working memory differences to be specifically related to the presentation of unexpected information. In our experiment, higher verbal span readers showed fewer returns to the introductory sentences (regressions out) than lower verbal span readers after reading both the expected and unexpected target concepts of the main text. Then, as expected, working memory differences were not specifically associated with the detection of inconsistent information. Nonetheless, these differences indicated the increased ability of higher verbal span readers to integrate the target concept with prior information, suggesting better accessibility to the memory representation. In contrast, lower verbal span readers seemed to experience difficulty integrating the target concept (expected and unexpected) with prior text information, which suggests that they had problems accessing their memory representation. This finding chimes with the assumption that less efficient readers are less able to maintain previous relevant information in working memory because they need these resources to process incoming information (Daneman & Carpenter, 1983).

Furthermore, we predicted individual differences in verbal working memory to be associated to the updating of the situation model. In line with this, higher verbal span readers exhibited shorter reading times (go–past time) than lower verbal span readers on the target words of the critical sentence, but only when the unexpected concept was presented. Therefore, the difference was exclusively found when inconsistent information was presented. This result demonstrated that higher verbal span readers were able to incorporate the unexpected concept into their mental representation and more importantly, discard the prior incorrect interpretation, thereby updating their situation model. In contrast, lower verbal span readers were able to activate the unexpected concept but they had problems discarding the inference generated in the introduction. Thus, low verbal span readers failed to update the situation model because they did not suppress the no longer relevant information. This finding also fits well with studies showing individual differences in the ability to suppress irrelevant information (e.g., Gernsbacher & Faust, 1991). In addition, these differences were specifically associated with the verbal domain of working memory with no influence of the visuospatial domain. Although the ability to update the contents of working memory has been commonly defined as an executive function (Carretti, Cornoldi, De Beni, & Romanò, 2005; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001), our results reflect that rather than having a general relationship with working memory, the ability to suppress no longer relevant information in the situation model depends specifically on the verbal domain of working memory. This interpretation is consistent with findings demonstrating that the impaired ability to suppress irrelevant information of children with poor comprehension is restricted to verbal working memory (Pimperton & Nation, 2010). Moreover, participants with higher verbal span made fewer regressions into the target words of the critical sentence than those with lower verbal span, when the expected concept was presented. This result was interpreted as the ability of higher verbal span readers to easily understand the critical sentence according to their mental representation of the story. Once more, this highlights the relationship between reading comprehension and the verbal domain of working memory. Additionally, the increased frequency of regressions to the critical sentence for lower verbal span readers could be reflecting comprehension monitoring, since it has been seen that the presentation of comprehension questions encourage understanding in low span readers (e.g., Hannon & Daneman, 1998).

Lastly, the product of comprehension (i.e., accuracy of responses) showed fewer correct responses when the concept presented was unexpected. This suggests that the context provided by the introduction exerted a general influence in the global comprehension of the story, making it easier to respond to critical sentences that were expected than unexpected. In addition, working memory was not associated with this, suggesting that the presentation of the story together with the critical sentence helped all readers to improve their reading comprehension.

We believe this is the first study reporting verbal working memory differences in the process of updating information using on–line measures of reading narrative texts and critical sentences. Our results show that readers are able to monitor their inferential comprehension detecting inconsistencies between their mental representation and text information. However, low span readers fail to successfully update their situation model, because their prior interpretation interferes with the new information. This seems to be due in particular to a problem in the ability to suppress no longer relevant information. Furthermore, this difficulty in suppressing irrelevant information is specifically connected with the verbal (not visuospatial) domain of working memory capacity, where lower verbal span readers are less able to suppress a prior incorrect interpretation requiring more rereading of the text to update the situation model.

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STUDY 3

Inferential Updating in Narrative texts: an ERP study

Pérez, A., Cain, K., Castellanos, M.C., & Bajo, T. (under review). Inferential updating in narrative texts: an ERP study. *Brain and Language*.

Abstract

We evaluated the process of inferential updating during text comprehension in adults. The introduction supported two plausible concepts (e.g., '*guitar/violin*'), although one was more probable ('*guitar*'). There were three possible continuations: a neutral sentence, which did not refer back to either concept; a no update sentence, referred to a general property consistent with either concept (e.g., '…*beautiful curved body*'); and an update condition, referred to a property that was consistent with only the less likely concept (e.g., '…*matching bow*'). Both working memory groups took longer to read the sentence in the update condition. In a final sentence, a target noun referred to the alternative concept supported in the update condition ('*violin*'). Only high working memory readers updated their initial incorrect interpretation (P3b) and integrated this new inference (N400) reading the update sentence. Low working memory readers had problems accurately representing semantically related inferential concepts, failing to update their situation model.

Keywords: updating information; inference making; working memory; P3b; N400.

3.3.1. Introduction

Successful text comprehenders construct an integrated, coherent and accurate mental representation of the state of affairs described by the text. The construction of this situation model requires the reader to go beyond a representation of the surface characteristics of the text, and to incorporate world knowledge from long–term memory (Kintsch & van Dijk, 1978). This is a dynamic process; the situation presented in a text is described incrementally and can, therefore, change as the text unfolds. As each new piece of information is processed, it must be integrated with the mental representation constructed thus far, which involves revising and updating the current situation model (O'Brien, Rizzella, Albrecht, & Halleran, 1998; Zwaan & Radvansky, 1998).

Situation model updating can involve the addition of new concepts or information, a change in the encoded relations between events, and also the elimination of information from the representation if it is no longer relevant (Radvansky & Copeland, 2001). Skilled comprehenders evaluate new information against the current representation. When consistent with the current situation model, readers readily map the new information onto the current structure, drawing inferences as necessary (Morrow, Bower, & Greenspan, 1989). When new information is inconsistent with the current model, comprehension difficulties may occur (O'Brien et al., 1998). In such circumstances, a successful comprehender may revise the current situation model, which may involve inferential processing or shifting to build a new substructure if there is a significant change in topic (Gernsbacher, 1990).

Despite widespread agreement that comprehension is a dynamic process that involves inferential processing and updating, readers may not always successfully perform these processes when new information contradicts the current model. In a classic example, O'Brien et al. (1998) found that participants took longer to read a sentence regarding a person's behavior when the behaviour contradicted earlier information, e.g., reading '*Mary ordered a cheeseburger and fries*' after '*Mary, a health nut, had been a strict vegetarian for ten years*'. This finding indicates that participants experienced difficulty integrating the new information into their mental representation, because the new information was inconsistent with the earlier inference that '*Mary did not eat meat*'. This comprehension difficulty was reduced, but still evident, in a qualified condition that provided an additional explanation for the character's behavior encouraging a revision of the previously made inference ('*Nevertheless, Mary never stuck to her diet when she dined out with her friends*'). If participants had successfully updated their mental representation to incorporate this qualification, there would have been no comprehension difficulty. Thus, when new information is inconsistent with prior parts of the text, successful understanding requires the revision of the situation model.

The combination of both inference making and updating information is what we have called inferential updating. That is, text comprehension sometimes involves updating the mental representation created from information explicitly stated in the text or from an inference that is supported by the text and incorporated in the situation model. Evidence to date from a number of different paradigms has shown that readers do not always successfully revise and update their mental representation (e.g., Rapp & Kendeou, 2009). In this paper, we aim to understand better the dynamics of the inferential updating process and to explore one reader characteristic that might explain why some readers have difficulties with this process: working memory.

The construction of the situation model draws on working memory resources, particularly those related to the central executive (Baddeley & Hitch, 1974) and executive functions (Lehto, 1996; Morris & Jones, 1990). Working memory has been found to influence both inference making (e.g., Morrow et al., 1989) and updating (e.g., Carretti, Cornoldi, De Beni, & Romanò, 2005; Dutke & von Hecker, 2011). Consequently, there are two (not mutually exclusive) reasons why working memory may constrain an individual's ability to update inferences that they have encoded in their mental representation, when new information prompts a different or more specific interpretation. First, the reader has to activate and maintain inferred information generated from previous parts of the text to evaluate incoming information, a typical process during narrative comprehension. Thus, a person with low working memory might not be able to detect inconsistencies in the text because he/she has not accurately activated and/or maintained previous non–explicit information (MacDonald, Just, & Carpenter, 1992; Whitney, Ritchie, & Clark, 1991). Second, if new information disconfirms a previous interpretation, the revision process involves not only the activation and detection of the new information that prompts the update, but also the inhibition of the previous incorrect interpretation, a process that readers with low memory may find hard (Carretti et al., 2005; Dutke & von Hecker, 2011).

In general, measures of working memory that tap the central executive component are related to reading comprehension (Daneman & Merikle, 1996). Research has demonstrated that there is a specific link between working memory and the essential processes of reading comprehension such as maintenance of the current ideas of the text, activation of new information, and inhibition of outdated information. Readers with high working memory capacity are more likely than those with weaker memory skills to make elaborative inferences when these are strongly supported by discourse context (St George, Mannes, & Hoffman, 1997). In addition, when presented with ambiguous sentences that allow more than one interpretation, readers with high memory capacity are better able than readers with low memory capacity to maintain competing representations until the ambiguity can be resolved (MacDonald et al., 1992), or they are less likely to commit to a specific interpretation than are low memory readers (Whitney et al., 1991). Finally, readers with high working memory capacity are better able to inhibit information that is no longer relevant than are those with weaker memory skills (Carretti et al., 2005; Dutke & von Hecker, 2011). This latter finding is congruent with studies showing that both adults and children with poor reading comprehension also have difficulties inhibiting no longer relevant information from memory (e.g., Cain, 2006; De Beni, Palladino, Pazzaglia, & Cornoldi, 1998).

From this evidence, it appears that it will be easier for readers with good working memory capacity to revise or update their interpretation of a text when they encounter new information because it will be consistent with one of the currently active interpretations of events, and/or the prior interpretation will be quickly discarded when the new information is activated. For readers with weaker working memory, a comprehension difficulty will occur if the new information disconfirms their (single) interpretation and/or the initial incorrect interpretation is maintained for too long, because of slow inhibitory processes.

Surprisingly, there are very few studies that have examined the process of inferential updating. One relevant study conducted by Dutke and von Hecker (2011) provides evidence that an individual's memory capacity is associated with updating the situation model. In their paradigm, a narrative provided information about social relations between protagonists. Participants with high memory scores were better able than a group with lower memory scores to maintain and recall the situation model and to discard an earlier representation that was incompatible with new information. Thus, in situations where updating is required – when the relations between concepts and events become better specified and less ambiguous as the text unfolds, readers with low working memory have difficulties updating at the situation model level.

Dutke and von Hecker's (2011) materials concerned the relational structure of text and, therefore, do not speak directly to the role of inferential updating during the construction of the situation model. One of the few studies exploring some aspects of what we have called inferential updating is the developmental study of Lorsbach, Katz, and Cupak (1998). In their experiment, children and adults read garden path passages, in which the introductory sentences supported two different interpretations of an object, one more likely than the other. All participants were equally likely to set up the expected inference, but the children were less able to inhibit this when subsequent text favoured the alternative concept and, therefore, required an update to the situation model. Although the processing of these texts clearly required listeners to update their situation model, the authors discussed their results in terms of competing inferences and did not explain their results in relation to the updating process.

Inferences and the updating of the contents of the situation model are critical to the construction of a coherent situation model (Graesser, Singer, & Trabasso, 1994). Therefore, an understanding of the accuracy and time course of updating an inference is fundamental for comprehensive theories of text processing. The study reported here investigated the relation between inferential updating and working memory in two important ways. First, we manipulated whether or not the updating of inferences was required at the situation model level. Second, we examined if participants with poor working memory skills were also poor at updating their situation model during reading. The purpose of our study was to explore the interplay between these processes by recording electrical brain activity during reading.

Event–related brain potentials (ERPs) are a robust means to study the time course of inference making and whether or not an update has been made. In relation to our goal, an interesting theoretical framework is the context–updating theory (Polich, 2003; 2007). This framework distinguishes two subcomponents of the P300: a central–frontal positivity or "P3a" (e.g., Debener, Makeig, Delorme, & Engel, 2005), which appears when an incoming information is evaluated as new or different with respect the current representation demanding attentional control; and a posterior positivity or "P3b" (e.g., Hartikainen & Knight, 2003; Kok, 2001), which is found when the context of the incoming stimulus involves updating by memory processes. Polich (2003) suggests a brain circuit between a top–down process in the frontal lobe driven by focal attention (P3a) and a bottom–up process in the temporo–parietal areas guided by memory updating operations (P3b). More important, some studies have demonstrated a selective relationship between the reduction of the P3b amplitude and a poor execution in several capacities as working memory (e.g., Evans, Sellinger, & Pollak, 2011); comprehension monitoring (e.g., Getzmann & Falkestein, 2011[8]); or conflicting response–performance (e.g., Trewartha, Spilka, Penhune, & Phillips, 2013). This evidence is crucial for the present experiment. Another component of interest in our study is the N400, which is an index of the ease with which the meaning of a word can be integrated into the current situation model (see Kutas & Federmeier, 2009; 2011, for a review). The amplitude of the N400 is attenuated when there is a good fit between the word being processed and the context, in comparison to a poorly fitting word. This attenuation of the N400 component has been demonstrated for words related to a causal inference supported by the previous text, both during

[8] Getzmann and Falkestein (2011) also observed a right lateralized activation of the P3a in high–performing older listeners compared to low–performing older and high/low–performing younger listeners, which they interpreted as a compensatory mechanism of age to improve comprehension monitoring.

text reading (Kuperberg, Paczynski, & Ditman, 2011; St George et al., 1997) and subsequent lexical decision (Steele, Bernat, van den Broek, Collins, Patrick, & Marsolek, 2012).

In our study, we used ERPs to gain a more detailed view of when readers update their situation model using the following paradigm. First, readers were presented with a three–sentence introductory text that could support two different concepts, e.g., '*guitar*' and '*violin*'. The introduction was written such that neither concept was mentioned explicitly, both were plausible, but one was considered more likely by independent judges. Readers were then presented with one of three possible conditions: a neutral sentence, which did not refer directly or indirectly to either concept (e.g., '*The concert takes place at…*'); a no update sentence, which mentioned a property consistent with either concept (e.g., '*…made of maple wood, with a beautiful curved body*'); and an update condition, in which the sentence referred to a property that was consistent with only the less likely concept (e.g., '*…made of maple wood, with a matching bow*'). The less likely concept was the one least supported by the introduction such that readers in this condition were required to update their situation model to ensure good comprehension. In the concluding sentence of the text, the final word was consistent with the concept supported in this latter update condition (e.g., '*violin*'). A preliminary proposal was that readers who successfully update their situation model should elicit an increase of the N400 in the no update compared to the update condition, since the semantic representation of the disambiguating word has not been incorporated to the situation model yet. This is because the N400 is an indicator of integration difficulty: the update condition should enable readers to integrate easily the target word into their situation model, whereas the no update condition should lead to difficulty because the target word is semantically inconsistent. In addition, considering that there is a strong relation between working memory and critical reading comprehension processes, such as updating and inference making, we also hypothesized working memory differences in the N400. Specifically, we predicted that those with high working memory scores would be more likely to update their situation model when reading the update sentence than those with low working memory scores, resulting in larger N400 (in the no update condition) for the high working memory group.

In relation to these hypotheses, a preliminary study of inferential updating process in adults (Pérez, Cain, Castellanos, & Bajo, 2012) was carried out. In this study, we compared the performance of adults with high and low working memory on two of the conditions described above: texts that prompted an update in the fourth sentence following the introduction and those that did not. We did not include the neutral condition described above in this pilot. We found that memory did not influence reading times for the update sentence, suggesting that readers with high and low working memory were equally likely to engage in additional processing, most likely detecting an inconsistency between the update information and their memory representation and/or revising their situation model in line with that information. The measurement of the N400 event–related potential revealed that both memory groups showed evidence of detecting a mismatch between the disambiguating word and the situation model. However, the electrophysiological pattern that emerged for each group was very distinct: the high memory group manifested a large N400 in the no update compared to the update condition in posterior regions; while the low memory group presented a relative difference between conditions generalized to all regions (main effect of condition). Therefore, we decided to carry out another study to clarify these results.

Table 4. Example of text used in the situation model updating task.

Dan was a gypsy who had played flamenco since childhood. Now he is a popular musician who plays all over the world. Today, he is giving a recital of his favourite works.	Introduction (bias *guitar*)
- The concert takes place at the prestigious national concert hall. - His instrument is made of maple wood, with a *beautiful curved body*. - His instrument is made of maple wood, with a *matching bow*.	Neutral No update Update
The public was delighted to hear Dan playing the **violin**.	ERP sentence
In the recital, Dan played his favourite works.	Comprehension sentence

Note. Participants saw the text in the neutral, no update or update condition. The word in bold in the ERP sentence was the disambiguating word.

The current study

Our pilot confirmed the situation model updating task as a promising framework for the study of inferential updating. However, in order to clarify the cognitive processes underlying the reading time data, as well as the relative difference found in the ERP amplitude, it is necessary to include a critical third condition – the neutral condition described above, in which the fourth sentence does not directly or indirectly refer to either of the two critical concepts. We included this third condition in the study we report here. We measured the reading time for sentence 4, which could either require no update to the situation model (as in the no update and neutral conditions) or an update (as described above and shown in Table 4; see Appendix F for full materials, p. 215). We also measured ERPs on the final word of sentence 5, in which the concept matched the inference prompted in the update condition but did not match the concept most strongly supported by the introduction for the other two conditions. According to the context–updating theory, our general proposal is that a frontal activation (P3a) will be found for the disambiguating word when readers have encountered the no update and neutral conditions compared to when they have read the update condition. This result would indicate the detection of information that is new or different with respect to the representation active in working memory. Furthermore, if readers successfully updated their situation model in line with the information provided by the update condition, they will demonstrate a reduced parietal activation (P3b) on reading this final disambiguating word compared to when they read the no update and neutral conditions. This is because readers would not draw on additional memory processes to revise their situation model, since the meaning of the disambiguating word is already encoded. Similarly, but as a consequence of a lack of updating, the same disambiguating word should elicit a N400 only in those conditions that did not help to update the context (no update and neutral) compared to the update condition, because the semantic representation of the less likely concept is not yet in their situation model.

Our predictions were as follows. First, in relation to the reading time for the sentence 4, we predicted longer reading times in the update condition relative to both other conditions. This prediction holds for both high and low memory readers, in line with our pilot. Longer reading times could reflect several (not mutually exclusive) processes: identification that the information is inconsistent with the current situation model, inhibition of the no–longer relevant inference that was originally encoded in the model, and the additional processing involved in generating an inference to update the situation model. Second, in relation to the ERP measures, we predicted no working memory group differences in the P3a subcomponent, since our preliminary study showed (behavioural results) that all participants were able to detect an inconsistency between the new concept and the general context of the introduction. Nevertheless, we predicted working memory differences in both the P3b and N400: high working memory readers will be able to accurately update their situation model when reading the update sentence compared to low working memory readers. If this is true, a reduction of the P3b in the update condition (e.g., reading '*violin*' after '*matching bow*') and an increase of the N400 in the no update and neutral conditions should occur for the high but not for the low working memory group. To our knowledge, this is the first electrophysiological study investigating working memory differences of the inferential updating process in reading comprehension.

3.3.2. Method

Participants

Seventy–seven people living in the city of Granada (Spain) with a mean age of 22.5 years old (range: 18–37 years) were recruited by an internet advertisement to participate for money. All were native English speakers and gave their consent to participate in the experiment. After they performed the two memory tasks (memory updating and reading span tasks), only participants with extreme working memory scores (see below) were selected to participate in the situation model updating task.

Materials

Memory updating task. We developed an English version of Carretti, Belacchi, and Cornoldi's (2010) memory updating task. Participants read lists of words, one word at a time, which increased in length as the trials progressed. The words were concrete nouns referring to objects of different sizes (large or small, e.g., '*ship*' or '*pea*'). The task was to recall the smallest object/s in the list. The number to be recalled was stated before each list and increased from 1 (Level 1) to 5 (Level 5), with a fixed presentation order. The recall set had to be updated as new words were presented. Participants were required to maintain the items in working memory to compare their sizes, to maintain activation of the smallest items in the specified set size, and to inhibit any previously activated words that no longer meet the criteria (that is to inhibit a large–size item when they heard the name of a smaller item). All participants completed all trials.

Reading span task. We used Daneman and Carpenter's (1980) reading span task. Participants read sets of sentences presented one by one and were required to recall the last word of each sentence, at the end of each set of sentences. The order of recall was not important but participants could not start with the last word of the last sentence. There were five levels increasing in difficulty from 2 (Level 1) to 6 (Level 5) sentences. A level was considered correct if participants recalled correctly each last word of at least three out of five (maximum) sets of sentences.

The scores of both memory tasks were the total number of words correctly recalled minus the total number of words incorrectly recalled (intrusions) in each memory task. These scores were used to divide participants into the high and low working memory groups.

Situation model updating task. We constructed 93 (3 practice, 90 experimental) five–sentence narrative texts, some modified from texts used by Lorsbach et al. (1998). The first three sentences (introduction) biased an inference generated at the situation model level (e.g., '*guitar*'). There were three versions of the fourth sentence: 1) in the neutral condition the sentence did not refer back to the inferable concept. Therefore, this sentence was neither consistent nor inconsistent with the introduction (e.g., '*The concert takes place at the prestigious national concert hall*'); 2) in the no update condition the information was consistent with the concept primed in the introduction (e.g., '*His instrument is made of maple wood, with a beautiful curved body*'); 3) in the update condition the information presented in sentence 4 prompted readers to revise their situation model so that only the alternative concept was encoded, rather than the concept supported by the introduction (e.g., '*His instrument is made of maple wood, with a matching bow*'). Reading times were the dependent variable for this sentence.

A pilot study with a two–alternative forced choice task confirmed that the two critical concepts were both supported by the fourth sentence (e.g., '*guitar*' for the no update, and '*violin*' for the update). Participants read the 3–sentence introduction, followed by one of the two versions of the sentence 4. They were instructed to mark the concept that the text was about. Seven participants completed each version of each text. In the final study, we included only texts for which the appropriate word was selected in both versions by a minimum of five participants. The word frequency for each of the two critical concepts was examined using the Word Frequency Guide database (WFG; Zeno, Ivens, Millard, & Duvvuri, 1995) and did not differ (M no update = 56.58; M update = 47.18, $t(89) = 0.27$, $p = .79$). The word length of the fourth sentence did not differ between conditions (Ms = 11.70, 11.46, and 11.81, for the neutral, no update and update conditions respectively: $F(2, 178) = 1.74$, $p = .18$). The fifth and final sentence concluded with a disambiguation word (e.g., '*violin*'), which was always incongruent with the concept supported by the introduction and congruent with the concept of the update condition in the fourth sentence. Consequently, the final disambiguation word was unexpected in the no update and neutral conditions and expected in the update condition. At the end of the text, a comprehension sentence was shown which required a true or false judgment, (e.g., '*In the recital, Dan played his favourite works*'). This sentence was included to encourage participants to read for meaning.

To provide empirical confirmation of concept preferences in our situation model updating task, we conducted an additional pilot study with twenty–two participants. Participants read the introduction of each text and were then presented with a single word. Their task was to decide (yes/no) if it fitted with the sense of the story. The word was either the concept in the no update condition, which was most strongly supported by the first three sentences (e.g., '*guitar*'), the concept in the update condition (e.g., '*violin*'), or another noun that did not fit the context (e.g., '*poker*'). Accuracy and response times were analysed separately. Results of the one–way ANOVA performed on the accuracy data showed a main effect of word type: $F(2,42) = 92.92$, $p < .001$, $p\eta^2 = .82$, because the participants were more likely to correctly accept the word in the no update condition ('*guitar*'; $M = 17.63$, $SD = 1.62$) and to correctly reject the word that did not fit the story ('*poker*'; $M = 18.68$, $SD = 1.52$) than to accept the update word ('*violin*'; $M = 10.59$, $SD = 2.61$). Further, when participants did accept the word in the update condition, they took longer to do so ($M = 2079.43$ ms) compared with response times to the no update word ($M = 1612.33$ ms), $t(21) = 3.72$, $p < .001$)[9]. This difference suggests that the concept in the no update condition was significantly more likely to be activated than the update concept, after reading the introduction, as intended.

Procedure

Materials were administered in two sessions. The first session took approximately 30 minutes and included the two memory tasks. The memory updating task was administered first. Before each word list, participants were informed of the number of words in the list and how many objects to recall. Each word was presented for 2 seconds. A question mark prompted recall and the participant said their response out loud. A practice trial preceded the experimental trials. The reading span task was completed next. Participants were instructed to recall the last word of each sentence and, before each block, they were informed of the number of sentences (and words to recall) in the trial. Participants read each sentence at their own pace. At the end of the trial, a white screen appeared and participants said aloud the words that they could remember. A practice trial preceded the experimental trials.

[9] Because the rejection search process for words that did not fit the meaning is different from the confirmatory search process for words that fit, we did not include the correct rejection of the nonstory condition in the response time analysis.

Before the second session, the scores of both working memory tasks were used to divide participants into two groups. The mean number of words recalled for the low working memory group was 21.11 (*SD* = 2.74; range = 16–24) in the memory updating task and 29.50 (*SD* = 8.03; range = 16–44) in the reading span task; the mean number of words recalled for the high group was 26.39 (*SD* = 1.50; range = 24–29) in the memory updating task and 68.39 (*SD* = 12.10; range = 47–86) in the reading span task. A t–test between groups confirmed our group selection procedure, where significant group differences were apparent in both tasks: memory updating, $t(34) = 7.17$, $p < .001$; and reading span, $t(34) = 11.36$, $p < .001$.

In the second session, participants completed the situation model updating task. This session took approximately 90 minutes and only participants in the low and high working memory groups took part. For this task, we placed the electrode cap onto the participant's head to record the EEG. Each trial started with a fixation point ('+') that remained on the screen until the participant pressed the 'B' key on the keyboard to present the first sentence. Participants read the first four sentences at their own pace, pressing the space bar to display the next sentence. The reading time of the fourth sentence (neutral vs. no update vs. update) was measured. The fifth sentence was presented word by word with a fixed duration of 300 ms per word. In addition, there was a delay of 700 ms after the disambiguation word to ensure that the electrophysiological activities of the event–related potential were registered. Finally, participants were presented with the true/false comprehension sentence. This always referred to information in the introductory sentences (equally distributed across the three sentences) and was included to encourage participants to read for meaning. Participants pressed the designated true or false key to respond. Each of 90 experimental texts was presented to each participant only once in one of the three conditions (neutral, no update or update) counterbalanced across participants. The task was administered in three blocks, keeping the same proportion (10 texts) in each condition per block. The same number of participants completed each condition, and the presentation of texts was randomized within block. A practice of 3 trials ensured that instructions were understood.

Apparatus

All tasks were presented by the E–prime software (Schneider, et al., 2002), administered on a 19" CRT video monitor (refresh rate = 75 Hz). For the situation model updating task, scalp voltages were recorded from a SynAmps2 64 channels Quik–Cap, plugged in to a Neuroscan SynAmps RT amplifier. The electrical signal was amplified with a 1–30 Hz band–pass filter and a continuous sample rate of 250 Hz. Ocular movements and blinks were also collected by two pairs of channels: a) the vertical electrooculogram situated in the left eye of the participant, with one electrode supra and another infraorbitally to measure blink artifact; b) the horizontal electrooculogram placed in the external canthi, with one electrode on the left and another on the right side to register eye movements. Impedances were kept below 5kΩ. Both blinks and ocular movements were corrected. In addition, trials with artifacts were rejected (3.12%), and in those cases where electrodes had a high level of artifacts (>1%), these were substituted by the average value of the group of nearest electrodes. Epochs with an interval between –200 and 800 ms with respect to the presentation of the target word (disambiguating word) were averaged and analysed. Baseline correction was applied using the average EEG activity in the 200 ms preceding the onset of the target as a reference signal value. Separate ERPs averages were developed for each condition for each participant. Individual averages were re–referenced off–line to the average of left and right mastoid. Six regions of interest (ROI) were extracted from the 64 channels (see Figure 6), keeping the criteria of 1) symmetry between hemispheres and 2) same number of electrodes (five sites)[10]: left frontal or LF (F1, F3, F5, FC3 and FC5); right frontal or RF (F2, F4, F6, FC4 and FC6); central or C (C1, C2, CZ, FCZ and CPZ); left parietal or LP (P1, P3, P5, CP3 and CP5); right parietal or RP (P2, P4, P6, CP4 and CP6); and occipital or O (O1, O2, POZ, PO3 and PO4).

[10] Because the magnitude of the components involved in the inferential updating process is still unknown, our regions of interest were selected taking into account a good representation of the different parts of the scalp.

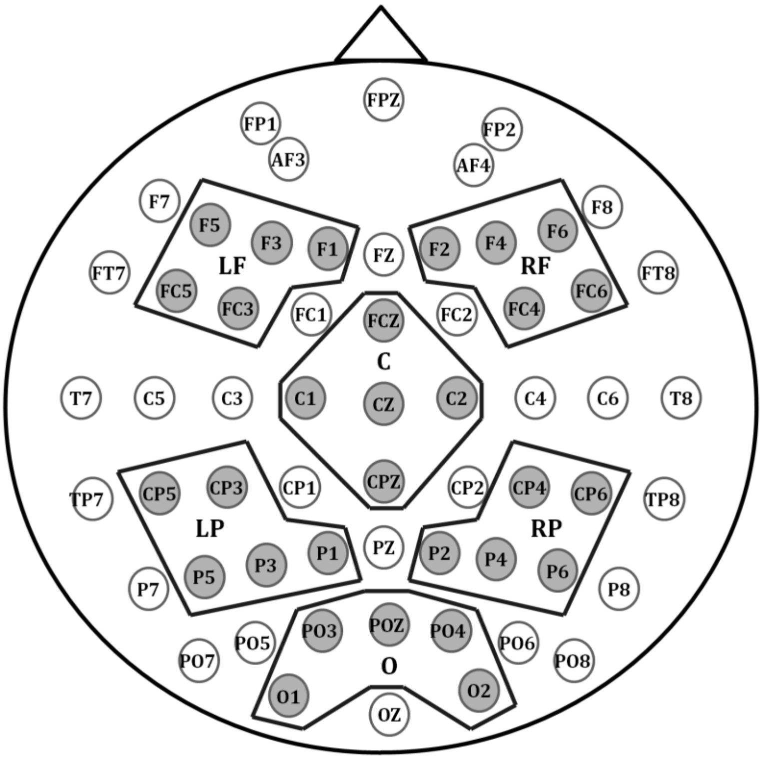

Figure 6. The six regions of interest (ROI): left frontal (LF); right frontal (RF); central (C); left parietal (LP); right parietal (RP); and occipital (O).

Statistical analyses

We report statistical analyses of thirty–six participants for all trials[11]. Working memory group was a between–subjects factor in all analyses. The behavioural analysis of the situation model updating task was conducted on RT (milliseconds) per sentence. In the ERP analyses, the mean amplitude was calculated in the window of 220–300 ms (P3a and P3b) and the window of 300–550 ms (N400) after the disambiguating word onset (see Figure 7). Outlier amplitude data per continuation, group and ROI was detected by the Box–Whisker plot, and replaced by the mean for both the P300 (3.70%) and the N400 (2.47%).

[11] Responses to the comprehension question were recorded only to ensure that participants were attending. The comprehension question always referred to the introduction (first three sentences), so did not affect either the behavioural (fourth sentence) or the electrophysiological (fifth sentence) data. T–test comparison on RT confirmed no differences between the sample without incorrect responses and the whole sample, $t(35) = 0.07$, $p = .95$.

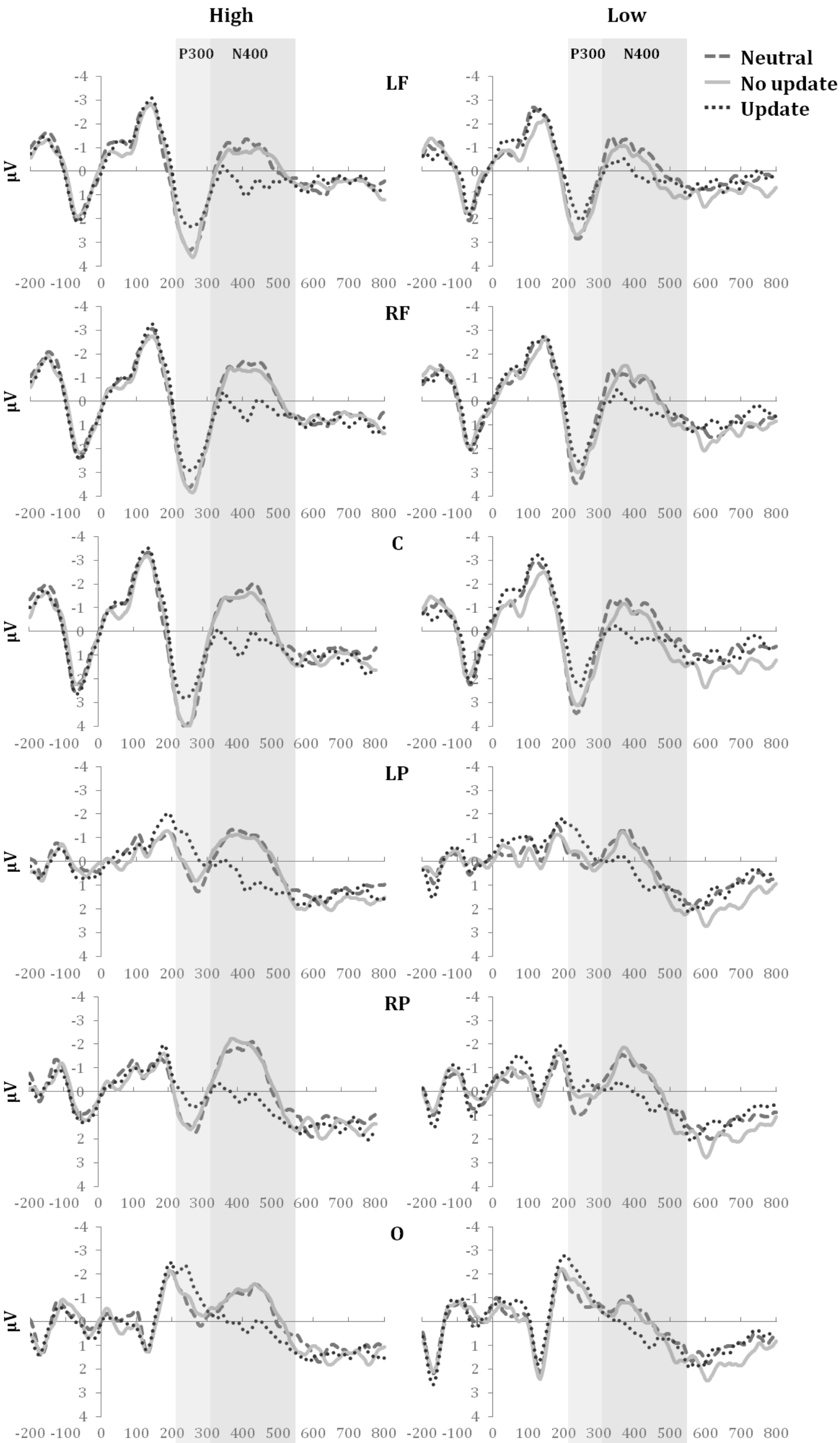

Figure 7. Graphical representation of the electrophysiological activity (in microvolts) found in both working memory groups (High and Low) in each region of interest (LF, RF, C, LP, RP and O). The columns indicate the temporal window of the components: the pale grey column shows the P300, and the dark grey column the N400. Conditions are also represented by different colors (see legend).

3.3.3. Results

Behavioural analysis: reading times in sentence 4

A mixed model ANOVA with working memory group (high vs. low) and condition (neutral vs. no update vs. update) was performed on RT per sentence. There was only a main effect of condition, $F(2, 68) = 11.27$, $p < .001$, $p\eta^2 = .25$, where the update required longer reading times (3075.75 ms) than the other two conditions: neutral (2800.56 ms), and no update (2714.43 ms). The memory group effect, $F(1, 34) = 1.82$, $p = .19$, and the group x condition interaction, $F(2, 68) = 1.82$, $p = .17$, were not significant (see Table 5 for means). T–test comparisons to confirm the locus of differences in the main effect of condition revealed that the update condition significantly differed from the neutral, $t(35) = 3.01$, $p = .005$, and the no update, $t(35) = 4.21$, $p < .001$, conditions. The comparison between the neutral and the no update condition was not significant, $t(35) = 1.43$, $p = .17$.

Table 5. Interaction between working memory group (High vs Low) and condition (Neutral vs No update vs Update).

		M	*SD*	Range
High	Neutral	2675.46	890.95	1534.57-4954.17
	No update	2630.92	763.23	1588.33-4148.77
	Update	2845.11	533.26	2002.83-3836.77
Low	Neutral	2925.66	651.37	1750.97-4406.50
	No update	2797.95	574.52	1684.80-3963.13
	Update	3306.39	761.91	1740.60-4647.20

Event–related potential analysis: amplitude in sentence 5

First, in order to see if both subcomponents of the P300 (P3a and P3b) could be distinguished in our data, we carried out a one–way ANOVA on the mean amplitude data in the time window of 220–300 ms, dividing ROI in central–frontal (C, LF and RF) and posterior (LP, RP and O) regions. The analysis showed a significant main effect of location, $F(1, 35) = 173.56$, $p < .001$, $p\eta^2 = .83$, because the central–frontal regions were significantly more positive than the posterior regions. Therefore, we conducted separate analyses for the P3a (C, LF and RF regions) and the P3b (LP, RP and O regions).

P3a analysis. A mixed model ANOVA with working memory group (high vs. low), condition (neutral, update, no update), and the three ROI[12] associated with the P3a (LF, RF, and C) was performed on the mean amplitude data in the time window of 220–300 ms. There was a tendency towards a larger positivity in the high memory group compared to the low memory group, $F(1, 34) = 3.36$, $p = .08$, $p\eta^2 = .09$. The main effect of condition was significant, $F(2, 68) = 3.87$, $p = .03$, $p\eta^2 = .10$, where, as predicted, the amplitude for the disambiguation word following the neutral and no update versions of sentence 4 resulted in larger positivity than that found in the update condition. There was also a main effect of ROI, $F(1.83, 62.28) = 5.83$, $p = .005$, $p\eta^2 = .15$, with larger positivity in the C and RF regions than in the LF region. No interactions were significant (all $p > .35$; see Figure 8a).

P3b analysis. A second mixed model ANOVA with working memory group, condition, and the three ROI related to the P3b (RP, LP, and O) was performed on the mean amplitude of the same temporal window. The main effect of group did not reach significance, $F(1, 34) = 1.00$, $p = .33$. There was a significant effect of condition, $F(2, 68) = 7.42$, $p = .002$, $p\eta^2 = .18$, because as predicted the amplitude in the neutral and no update conditions was more positive than in the update condition. There was also a main effect of ROI, $F(1.88, 64.02) = 72.11$, $p < .001$, $p\eta^2 = .68$, because the two parietal regions (LP and RP) were significantly more positive than the O region. In addition, there was a significant two–way interaction between the working memory group and condition, $F(2, 68) = 3.79$, $p = .03$, $p\eta^2 = .10$, where, as expected, only the high memory group presented a more positive amplitude in the neutral and no update conditions compared to the update condition (see Figure 8b). No other interactions reached significance (all $p > .10$).

To identify the locus of the interaction between working memory group and condition, planned comparisons between conditions were carried out for each memory group separately (with a Bonferroni correction setting the alpha at .008).

[12] ROI values are based in a Greenhouse–Geisser correction.

For the high memory group, significant differences between the update and both the neutral and the no update conditions were apparent, $t(17) = 4.02$, $p < .001$; and $t(17) = 3.13$, $p = .007$, respectively; whereas the neutral and no update conditions did not differ $t(17) = 1.26$, $p = .22$. A different pattern was apparent for the low memory group: none of the contrasts reached significance (all *ps* > .44).

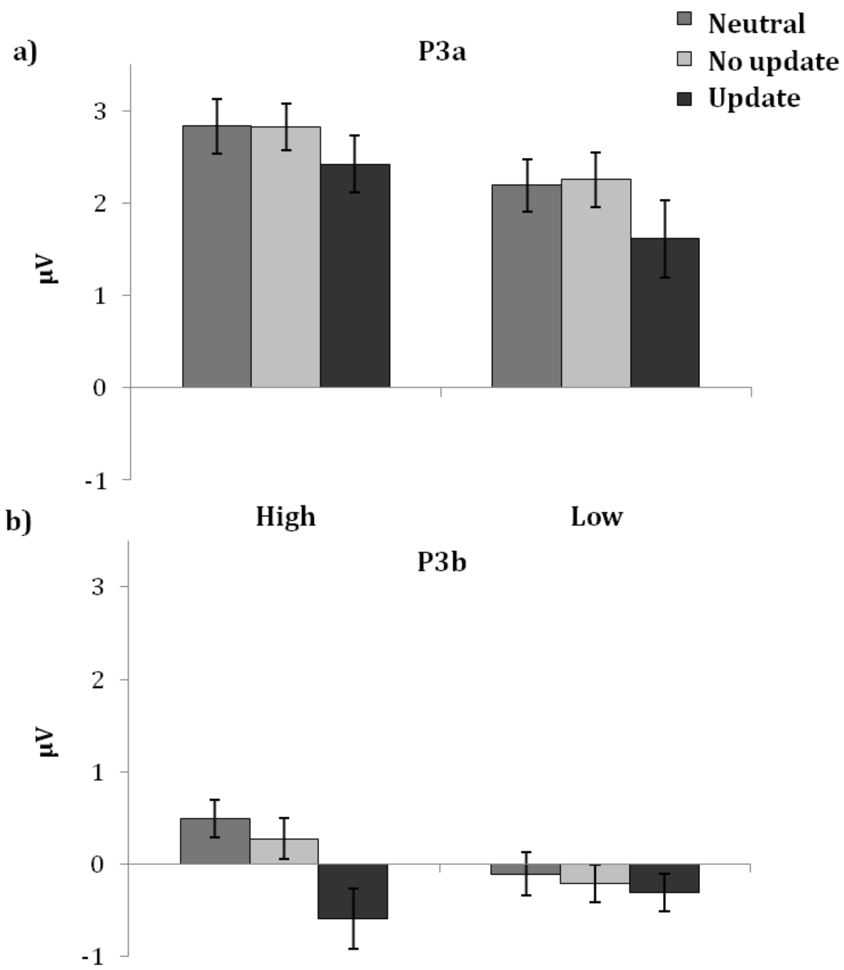

Figure 8. ERP results of the interaction between working memory group (High vs Low) and condition (Neutral, No update and Update) in the P300 component. The panel 'a' shows the activation of the P3a subcomponent (central–frontal regions), while the panel 'b' shows the brain activity of the P3b subcomponent (posterior regions).

N400 analysis. A third mixed model ANOVA with working memory group, condition and the six ROI was performed on the mean amplitude data in the time window of 300–550 ms. The main effect of group did not reach significance, $F(1, 34) = 0.91$, $p = .35$. There was a main effect of condition, $F(2, 68) = 21.84$, $p < .001$,

$p\eta^2$ = .39, because as predicted the amplitude in the neutral and no update conditions was more negative than in the update condition. There was also a tendency toward a main effect of ROI, $F(2.36, 80.10) = 2.65$, $p = .07$, $p\eta^2 = .07$, with less negativity in the LP region. In addition, there were two significant interactions: one between condition and ROI, $F(6.02, 204.77) = 3.94$, $p = .001$, $p\eta^2 = .10$, with the neutral and the no update conditions always being more negative than the update condition, particularly in the RP region, $t(35) = 7.23$, $p < .001$, and $t(35) = 6.60$, $p < .001$, respectively; and the other between group and condition, $F(2, 68) = 3.85$, $p = .03$, $p\eta^2 = .10$, where only the high memory showed more negative amplitude in the no update condition compared to the update condition. (see Figure 9). The two–way interaction between group and ROI and the three–way interaction were not significant, $F(5, 170) = 2.08$, $p = .07$, $p\eta^2 = .06$; and $F(10, 340) = 1.29$, $p = .23$, respectively.

Once more, to identify the locus of the interaction between working memory group and condition, we conducted planned comparisons between conditions for each memory group separately. As before and as predicted, the high memory group showed larger negativity (N400) in the neutral condition, $t(17) = 6.80$, $p < .001$, and the no update condition, $t(17) = 6.02$, $p < .001$, compared to the update condition. Furthermore, the neutral and the no update conditions did not differ, $t(17) = 0.19$, $p = .85$. In contrast, the low memory group showed larger negativity (N400) in the neutral compared with the update condition, $t(17) = 3.44$, $p = .003$, but there was no difference between the no update and the update condition, $t(17) = 1.46$, $p = .16$; nor between the neutral and the no update condition, $t(17) = 1.49$, $p = .15$.

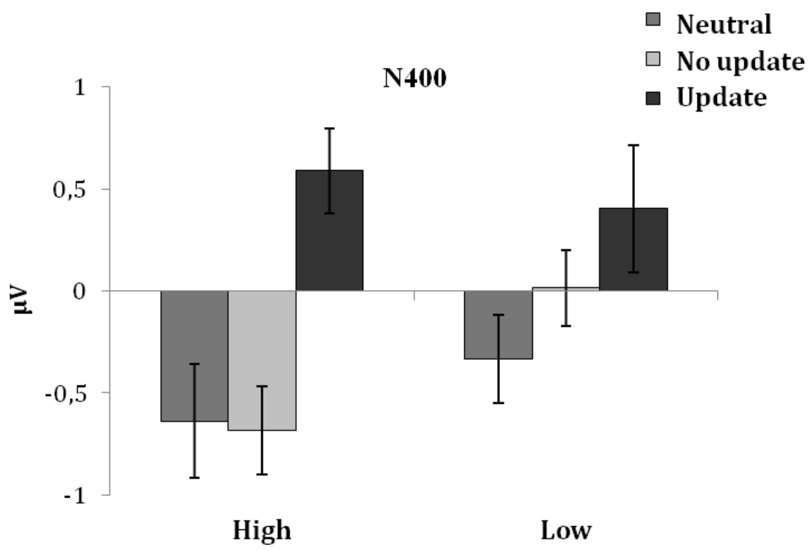

Figure 9. ERP results of the interaction between working memory group (High and Low) and condition (Neutral, No update and Update) in the N400 component.

3.3.4. Discussion

Our goal was to investigate the dynamics of inferential updating in relation to adult readers' working memory capacity, using both behavioural and electrophysiological measures. The behavioural results reflected longer reading times in both working memory groups when they read a sentence that prompted updating in comparison to a neutral and a no update sentence. On the other hand, the electrophysiological results indicated differences between the working memory groups for specific ERP components. The division by subcomponents in the P300 demonstrated that memory groups did not differ in the amplitude of the P3a: both memory groups presented larger positivity in the neutral and no update conditions compared to the update condition. The pattern of findings for the P3b differed by working memory group. The high memory group showed significantly larger positivity in the neutral and no update conditions compared to the update condition. In contrast, the low memory group did not differ between conditions. Similarly, for the N400 component, the high memory group demonstrated larger negativity in the neutral and no update conditions than in the update condition. In contrast, the low memory group did not show a difference between the neutral and the no update condition, although a difference was apparent between the neutral and the update condition.

In our situation model updating task, the first three sentences (introduction) provided a general context that facilitated at least two plausible inferences, one of which was more likely than the other. The fourth sentence was either neutral, in that it did not refer to the critical concept in the story; did not prompt an update, because it was consistent with both concepts supported by the introduction; or it prompted an update to the situation model because the description was consistent with only the less likely concept. In line with our pilot study, we found a large cost effect when participants read sentence 4 in the update condition, compared to the neutral and no update conditions. This effect demonstrated that participants detected an inconsistency between the introduction and the concept supported in the update condition. This cost effect was apparent only in the update condition. The reading times for the no update condition did not differ from the neutral condition, demonstrating that the context of the introduction primed only the most plausible concept. If both concepts were active in memory, participants should have shown no differences in RTs between the update and no update conditions. Further, there were no differences in RTs between the working memory groups: all participants took longer to read the sentence in the update condition than the neutral and the no update conditions. This was congruent with our preliminary study.

The reading time data alone do not identify if both groups engaged in processing additional to the detection of a mismatch, such as successfully updating their situation model and inhibiting the earlier interpretation of the concept. The ERP data recorded for the subsequent disambiguating word speak to that. As we have already pointed out, several components were of interest here. The analysis of the P300 window demonstrated a clear distinction between the P3a (central–frontal activation) and the P3b (posterior activation) subcomponents. Critically, there were no differences between the working memory groups for the P3a, while these differences were apparent for the P3b. According to the context–updating theory (Polich, 2003; 2007) the P3a takes place when an incoming information demands attentional control because is evaluated as 'new' or 'different' with respect the current memory representation (top–down process); in contrast, the P3b appears when that incoming information forces subsequent attentional resources to favour context updating by memory operations (bottom–up process). Although this theoretical framework has been developed using a traditional attentional task (oddball paradigm), the results found with our situation model updating task fit perfectly within this framework. First, the common pattern of the larger P3a in the no update and neutral conditions for both memory groups indicates that all readers required greater attentional control when the earlier text had not prompted an update. This means that both high and low working memory readers were able to evaluate the disambiguating word as new or different with respect to their memory representation (detection of inconsistency). From our point of view, this is convergent with the reading time data: both memory groups were aware that the concept encoded in their situation model was not appropriate when they read sentence 4 in the update condition. Additionally, according to the context–updating theory, the tendency towards larger positivity in the high memory group suggests that this group required fewer attentional resources than the low group to evaluate the disambiguating word as 'new'. Second, the group differences found for the P3b component indicate that the two groups engaged in different processing when they read sentence 4 in the update condition. The smaller P3b found for the high working memory group in the update condition relative to the other two conditions suggests that this group not only detected that the information in sentence 4 was not consistent with the concept activated in their situation model (as indicated the longer RTs and the P3a), but had successfully updated their situation model when reading this information. As a result, the disambiguating word did not require additional memory processes after the update condition because that information was already incorporated into the mental representation. In contrast, although the low working memory group also showed the detection of inconsistent information with their memory representation (longer RTs and P3a), they appeared not to have updated their situation model when reading sentence 4, because there were no differences in the amplitudes of the P3b for any conditions. The distinction found between the P3a and P3b clearly demonstrates a dissociation between the process to detect information that does not match with the current memory representation (top–down process), and the process to update inferential information by integrating this into the mental representation of the text (bottom–up process). We further explain these results in terms of the generation of the situation model. Since low working memory readers can detect the presentation of new information, we believe that they built a coherent situation model from the introduction of the text. However, because they seem to have problems incorporating that information into their representation, we also believe that they have difficulty constructing a 'precise' and 'accurate' situation model. The N400 component sheds light on this issue.

The analysis of the N400 also reflected a different pattern depending on the working memory group. As we predicted, the high memory group showed larger negativity in the neutral and no update conditions compared to the update. This finding signals their ability to detect a semantic inconsistency between the disambiguating word and their current representation, when an earlier update was not prompted. In addition, it also demonstrates that high working memory readers were able to integrate the prior updating sentence into their situation model of the story. In contrast, the low working memory group manifested a different electrophysiological pattern. As expected, these readers showed no significant difference between the no update and the update condition, indicating that they had not successfully revised their situation model when prompted to do so. However, in contrast to our predictions, they presented a larger negative amplitude in the neutral condition compared to the update condition. From our point of view, different explanations underlie these results.

On the one hand, the lack of difference between the no update and the update condition strongly suggests that the low memory group had difficulty in accurately representing the specific concept in their situation model. Interestingly, both critical concepts (e.g., '*guitar*/*violin*') shared similar semantic properties, which could potentially interfere and make it difficult to integrate the specific concept into an accurate situation model. In accordance with this, some studies have shown the pervasive effect of semantic interference to updating the contents of working memory (e.g., Szmalec, Verbruggen, Vandierendonck, & Kemps, 2011). On the other hand, the difference found between the neutral and the update condition suggests that low memory readers were able to detect a semantic inconsistency between the context of the introduction (e.g., idea of '*guitar*') and the final word (e.g., '*violin*').

We have already discarded the possibility that both concepts were activated in memory, since the behavioural results demonstrated a clear cost effect for only the update condition. The neutral condition differed from the other two conditions because it presented information that did not refer to the specific concept. If this difference resulted in a change of story focus in the neutral condition, the inconsistency between the concept supported by the introduction and the disambiguating word would be less apparent because that aspect of the story would not be foregrounded and therefore less activated in memory (Glenberg, Meyer, & Lindem, 1987; Radvansky & Copeland, 2001). This reduced focus or activation may be more apparent for readers with low working memory capacity who have been found to experience difficulties detecting change when across several sentences (Daneman & Carpenter, 1980; Oakhill, Hartt, & Samols, 2005).

Finally, it is important to remember that text comprehension is not an all–or–nothing process. In this sense, the updating of inferential information can vary according to the degree of accuracy with which a situation model is generated. This supports the distinction found here between the P3a and P3b, and accounts for the issue that amplitude differences found between working memory groups are due to differences in magnitude rather than qualitative differences. This is consistent with other studies of adult language processing, where differences between high and low working memory groups are typically quantitative rather than qualitative (e.g., Daneman & Carpenter, 1983).

Conclusions

In sum, this is the first study to report ERP data for inferential updating of readers' situation models. We have identified where in the reading process poor working memory readers have difficulties with situation model updating and also demonstrated distinct electrophysiological patterns that can be used to study this phenomenon further. Our results strongly suggest that readers with low working memory are able to detect coherence breaks when processing text, but that they have difficulties excluding a prior wrong interpretation because they fail to update and integrate new information to ensure an accurate situation model.

Acknowledgements

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4. GENERAL DISCUSSION

The general aim of this thesis was to investigate some high–level cognitive processes of reading comprehension that are involved in the construction of a situation model representation. Concretely, we refer to the processes of inference making, comprehension monitoring and updating information. Moreover, we also investigated whether performance on these high–level comprehension processes was predicted by individual differences in working memory. In addition, we explored the possibility that these processes were specifically restricted to the verbal domain of working memory, without the involvement of the visuospatial component. In relation to our general aims, in the following sections we will summarise the main results of our three experimental studies (section 4.1.), and then to discuss the implications of these results to inference making (section 4.2.), comprehension monitoring and updating information (section 4.3.), and working memory capacity (section 4.4.). Furthermore, we will finish the general discussion highlighting the most relevant conclusions (section 4.5.).

4.1. SUMMARY OF THE MAIN RESULTS

The focus of the first study (Study 1; Pérez, Paolieri, Macizo, & Bajo, 2014), was to determine whether knowledge–based inference making is modulated by working memory. Although previous work has demonstrated a relationship between working memory and the generation of inferences in general (e.g., Daneman & Green, 1986; St. George, et al., 1997; Virtue, et al., 2006), we know little about how working memory might influence different types of inferences. Therefore, we investigated participants' ability to generate three knowledge–based inferences that differ in their way to demand information from the text. To do so, we presented paragraphs and readers had to answer off–line comprehension sentences. We found that working memory was differently associated with the three types of inferences. The high and low working memory groups did not differ in their ability to make associative inferences, which could be generated simply by linking information in the text with background knowledge. However, working memory capacity was related to the two types of inferences (explicative and predictive) that required readers to link information in the text with background knowledge to generate causal relations: low working memory readers were poorer on both of these. This pattern of results suggests that working memory capacity influences knowledge–based inferences in relation to causality. This is interesting since it indicates that inferences requiring world knowledge from long–term memory demand the involvement of working memory when they are strongly connected by causal referents on the text.

Based on the findings from Study 1, in the second study (Study 2) we focused on knowledge–based inferences that were strongly supported by the causal constraints of the text context. In addition we investigated the relation between causal inferencing and two other cognitive processes: comprehension monitoring and the updating of information. The ability to monitor inferential information has been already investigated (e.g., Poynor & Morris, 2003), but studies to date have not established whether readers update their situation model during reading when new information that is inconsistent with the current mental representation is presented. To investigate these processes, in the study, the knowledge–based inference was subsequently confirmed by an expected concept, or disconfirmed by an unexpected concept. The results of Study 2 indicated, first, that readers typically generate knowledge–based inferences when they are supported by context: we found shorter reading times when the target concept was expected compared to when it was unexpected, that is, not strongly supported by the context. Thus, these results replicated previous findings indicating that adult readers are able to detect information that is inconsistent with a prior wrong interpretation (inferential monitoring).

Second, to see if readers updated their situation model we presented a critical sentence including congruent or incongruent information in relation to the prior concept. In general, the previous knowledge–based inference continued exerting an influence even when the unexpected concept has been presented: we found longer reading times in the confirmation of the unexpected concept than the confirmation of the expected concept in the congruent critical sentences. This result suggested difficulties to discard the expected interpretation and thus, to update the situation model. In addition, in Study 2 we also wanted to further explore the role of working memory on comprehension monitoring and updating, and if this role was domain specific (verbal versus visuospatial working memory).

Results suggested that readers with high verbal working memory were able to discard the prior wrong inferred idea, while readers with low verbal working memory experienced some difficulty: high verbal span readers took shorter times than low verbal span readers in the target words of the critical sentence only when the unexpected concept had been presented. Interestingly, this pattern was not found for readers differing in visuospatial working memory suggesting that only verbal working memory is related to the updating process. Nevertheless, despite these results, a significant amount of knowledge–based inferences affected the product of comprehension: we observed a smaller number of correct responses when the unexpected versus the expected concept was presented.

Our Study 2 demonstrated an apparent dissociation between the detection of inconsistent information (comprehension monitoring) and the ability to suppress the outdated information from the situation model (updating information). In fact, individual differences in working memory capacity were associated principally to the updating process. Beyond the distinction between these two processes, we did not know yet what exactly happened when readers with high and low working memory encountered the inconsistent information. To understand this issue, we carried out the third study.

Study 3 was designed to investigate updating information by comparing performance on three text types. Each text had the same introduction that supported the knowledge–based inference of a key concept, but one continuation required the reader to make an inference different to the one supported by the introduction (update sentence), whilst the other texts had continuations that were either consistent with the prior inference (no update sentence) or stated neutral information (neutral sentence). We found that all readers took longer to read the continuation when a new inference was required, regardless of working memory capacity. This result demonstrated once more that all readers were able to generate the knowledge–based inference in the prior context. Moreover, it also demonstrated the detection of the current incompatible inferential information. Hence, again, readers successfully monitored inferential information.

To determine if readers had actually updated their situation model we included a final sentence presenting a word that uncovered the story (disambiguating word). This word was always inconsistent with the prior knowledge–based inference and consistent with the new inference supported by the update continuation. By measuring ERPs in this word, the results of Study 3 showed a clear distinction between the P3a (central–frontal activation) and the P3b (posterior activation) subcomponents. Critically, there were no working memory differences in the P3a, which according to the context–updating theory (Polich, 2003, 2007) signalled that both high and low working memory readers detected an inconsistency when no update information has been previously provided. Nonetheless, working memory differences were apparent in the P3b: high working memory readers manifested a facilitation (smaller P3b) when previous update information had appeared, which was interpreted as a successful updating of their situation model during reading; in contrast, low working memory readers did not benefit from prior updating information (no differences in the P3b between conditions), indicating that they have not updated their memory representation. This dissociation found between the P3a and P3b suggested different information routes: a *top–down* route by which a coherent mental representation allows to detect inconsistent information (comprehension monitoring), and a *bottom–up* route whereby the new inferential information is integrated (updated) into the situation model.

Finally, we also found working memory differences in the N400: high working memory readers showed larger negativity when no update information had been presented. This result reflected their good ability to perceive a semantic incongruence and therefore, to construct an accurate mental representation; on the contrary, low working memory readers did not show differences after the presentation of the no update and update information. This result indicated that low working memory readers did not seem to detect the semantic incongruence between the prior inferred idea and the new concept and thus, suggesting possible difficulties in accurately representing the specific concept in the situation model.

4.2. IMPLICATIONS FOR INFERENCE MAKING

The ability to extract implicit information from a text is a fundamental process for comprehension. As we have seen, inferences are used by readers to establish coherence in the mental representation of a text. They enable the reader to make connections between just–read information and previous segments of the text and/or prior knowledge (e.g., Graesser, et al., 1994; Magliano, et al., 1999; Zwaan & Radvansky, 1998), and support the integration between relevant ideas (e.g., Kintsch, 1998; Magliano, et al., 1999; Zwaan, et al., 1995). The findings of our three experimental studies have implications to how inference making supports coherence and integration in text comprehension. According to this, in Study 1 we used an inference's classification that distinguished between three types of knowledge–based inferences: explicative, associative and predictive (Trabasso & Magliano, 1996). The three inferences required to connect text information by means of prior knowledge (from long–term memory), but they differed in the way that background knowledge allowed to connect text information. Explicative or backward inferences demanded prior knowledge to connect previous parts of the text; predictive or forward inferences required prior knowledge to connect possible future outcomes; and associative or concurrent inferences only connected the current information with prior knowledge. In this sense, since the generation of explicative and predictive inferences compared to associative inferences forced the connection of a larger amount of text information, the coherence provided by these two types of inferences was higher, but also more difficult to reach: low working memory readers performed poorly in both explicative and predictive inferences. This was directly related to causality. In order to supply coherence readers must retrieve prior knowledge to explain causal antecedents or predict causal consequences. Therefore, readers that were less able to maintain information in working memory failed to establish causal relationships and thus, constructed a less coherent situation model. This result is consistent with studies showing the importance of causality in inference making (e.g., Millis & Graesser, 1994; Singer, et al., 1992; Sloman, 2005; Walsh & Johnson–Laird, 2009), and the role of causal inferences in providing explanatory coherence (Gernsbacher, 1990; Graesser, et al., 1997; Kuperberg, et al., 2010; Magliano, et al., 1993; Singer, 1995).

Additionally, our findings emphasized the involvement of causal relationships to link text information. In relation to this, the Causal Network model (Trabasso, et al., 1989) highlighted the role of causal relationships in the connection of text information. Although we used a different way to categorise the causal connections established in a text (causal antecedents and consequents), the relationships defended by the Causal Network model (enabling, psychological, motivational and physical) were implicit in our explicative and predictive comprehension sentences. For example, the explicative sentence '*The pale men were coward because they hunted with powder*' required a psychological relationship between the interpretation of the narrator (an indigenous) and the way to hunt 'with guns'. In the same way, the predictive sentence '*The hunters expected to trade with the stones that they would find*' required to connect the motivational interest of the hunters with the idea of 'precious stones'. From our point of view, it is more important to distinguish the function that plays the inference (e.g., explain or predict) rather than the content of information (e.g., physical or motivational). Therefore, the similarities found between our experiment and the Causal Network model's classification justify the use of a broader distinction of causal relationships based on functionality, as it does the differentiation between explanations and predictions.

Moreover, although some models of comprehension have underestimated the role of knowledge–based inferences in reading comprehension (e.g., Magliano, et al., 1999; Trabasso, et al., 1989; Zwaan & Radvansky, 1998; Zwaan, et al., 1995), our off–line comprehension sentences in Study 1 demonstrated that knowledge–based inferences were essential to provide coherence to the global comprehension of the story. This is congruent with the Constructionist theory (Graesser, et al., 1994), which defends that knowledge–based inferences make possible the generation of explanatory arguments that help in the construction of a text meaning and benefit text coherence (e.g., Magliano, et al., 1999). It is important to clarify here that beyond the conclusive classification between explicative and predictive inferences that we used in Study 1, several studies have found that explanations may facilitate the prediction of future behaviours (Anderson & Ross, 1980; Einhorn & Hogarth, 1986; Lombrozo & Carey, 2006; Ross, et al., 1977).

Consequently, knowledge–based inferences are necessary to explain and predict text information connecting it with prior knowledge by means of causal relationships. Nevertheless, although the explicative, predictive and associative inferences were defined as knowledge–based inferences (Trabasso & Magliano, 1996), we believe that the explicative and predictive inferences have also to do with text–based inferences. As we have seen, explanations entail to establish a bridge between the current information and prior parts of the text, while predictions need to do it between the current information and possible upcoming events. According to this, our causal knowledge–based inferences were supported by text–based inferences. This is similar to the idea that we tried to reflect when we explained that text–based inferences may require to retrieve prior knowledge from long–term memory to allow the connection of text information (see Figure 3, p. 19, dotted arrow). As a result of this combination, we propose that some inferences such as explanations and predictions may require both types of processes: the activation of prior knowledge while reading the current text information and the connection of this retrieved information with previous parts of the text or possible future outcomes.

Furthermore, our Study 2 and 3 also shed some light to the inference making process. In both experimental studies, the prior context of narratives primed an inference based in world knowledge, and this knowledge–based inference was strongly facilitated by the causal constraints of the text. Importantly, the inference created an idea about the general context of the story, which means that readers generated an 'expectation'. The Landscape model (Linderholm, et al., 2004; Tzeng, van den Broek, Kendeou, & Lee, 2005; van den Broek & Gustafson, 1999; van den Broek, et al., 2005) has recognised the role of reader's expectancy to the construction of the situation model. In this sense, readers' representation depends on the expectations about events that they believe would occur as the story unfolds. This view is crucial to interpret our results: readers constructed the core of their mental representation based on an expectation of what was the text about. In fact, this expectation was later confirmed by longer reading times in the subsequent inconsistent information (unexpected concept in Study 2 and update sentence in the Study 3). Therefore, readers generate expectations during reading, which help them to provide global coherence to the story and detect inconsistent information if a coherence break occurs.

Empirical evidence of expectancy violation in reading comprehension has been obtained with multiple materials and paradigms (e.g., Carreiras, Garnham, Oakhill, & Cain, 1996; Duffy & Keir, 2004; Klin & Myers, 1993; Kutas & Hillyard, 1980; Rayner, Warren, Juhasz, & Liversedge, 2004; Trabasso & Suh, 1993; Warren, McConnell, & Rayner, 2008). For example, Kutas and Hillyard (1980) examined ERPs when readers encoded sentences with a moderate (e.g., '*He took a sip from the waterfall*') or strong (e.g., '*He took a sip from the transmitter*') semantic violation. They found a larger N400 potential in the strong semantic incongruity than in the moderate semantic incongruity, indicating a larger disruption of reader's expectation when semantic information was highly inconsistent. These results are congruent with the N400 potential found in causal unrelated sentences compared to highly causally related and intermediately related sentences (Kuperberg et al., 2010), and demonstrate the importance of reader's semantic expectation in reading comprehension. Some of our ERP results fit with these findings: readers with high working memory capacity manifested a N400 potential in the disambiguating word when they had read the neutral and no update sentences in comparison to when they had read the update sentence. However, we used texts instead of sentences and the information of the texts was inferential until the disambiguating word. Therefore, we add to previous finding by showing that reader's semantic expectations are also decisive in the construction of the situation model, and highly constraint contexts may facilitate the activation of expectations by also facilitating the generation of inferences. In addition, we also found that low working memory readers did not show the N400 in the disambiguating word after reading the no update compared to the update sentence. Since the two possible concepts of this task were semantically similar (e.g., '*guitar/violin*'), we concluded that less skilled memory readers may have difficulties to accurately represent an appropriate inferential concept, when the information semantically interferes with another concept. This interpretation suggests the idea that less skilled memory readers could have problems to generate a proper expectation when the context is inferentially ambiguous.

To sum up we have demonstrated that knowledge–based inferences such as explanations and predictions are involved in the construction of the situation model by connecting text information that is causally related (antecedent or consequent referents). This highlights the idea that some inferences combine both text information and prior knowledge, indicating that differentiation between text–based and knowledge–based inferences is not so clear cut. In addition, we have emphasised the role of knowledge–based inferences in highly constrained contexts, where the reader's semantic expectations are vital to the situation model. Finally, we suggest the possibility that less skilled working memory readers may have problems accurately representing semantically similar information because the conceptual similarities that may share the two (or more) information compete between them causing interference. In the next section we will discuss how inference making interacts with the cognitive processes of comprehension monitoring and updating information.

4.3. IMPLICATIONS FOR COMPREHENSION MONITORING AND UPDATING

The metacognitive ability to supervise and evaluate our own understanding of a text is, together with inference making, a crucial process for comprehension. Thus, in order to construct a coherent and integrated situation model, readers must continuously monitor the incoming information comparing it with previous parts of the text and prior knowledge (e.g., Magliano, et al., 1999; Zwaan & Radvansky, 1998; Zwaan, et al., 1995). In fact, many studies have demonstrated that the presentation of inconsistent or contradictory information produces a coherence break in the mental representation (e.g., Cain, et al., 2004; Kinnunen & Vauras, 1995; Magliano, et al., 2001; Nilsen, et al., 2008; O'Brien, et al., 1998; Rinck & Weber, 2003). In this sense, the literature of comprehension monitoring has distinguished two phases (Baker, 1985). On the one hand, an earlier phase of evaluation, in which the consistency of the current information is examined; if the information is evaluated as inconsistent or incompatible with the active representation, readers detect a disruption in text comprehension (e.g., Huitema, et al., 1993; Orrantia, et al., 2013; O'Brien, et al., 1998; Vauras, et al., 2008). On the other hand, only when an inconsistency has been detected, a later phase of regulation appears, in which readers try to revise or repair the incompatible information. In the present thesis we have specifically focused in the repair process whereby prior activated information is replaced with new incompatible information, which is known as updating information process. Our Study 2 and 3 disentangle the distinction between the monitoring of inconsistencies (evaluation phase) and the updating information (regulation phase) processes. We will now describe the implications of our results for these two cognitive processes.

As we mentioned in the previous section, the prior context of the narrative texts used in the Study 2 and 3 facilitated the generation of an inference. This inference was subsequently a) confirmed or disconfirmed (expected and unexpected respectively) in Study 2; or b) not referred, inferentially referred, or inferentially disconfirmed suggesting a new alternative (neutral, no update and update respectively) in Study 3. In both experimental studies readers took longer to read the information that was inconsistent with the prior inference (unexpected or update conditions) than the information that was consistent (expected or no update conditions) or even uninformative (neutral condition). These results demonstrated that readers detected a mismatch between the inconsistent information and their mental representation and thus, they were able to monitor their inferential comprehension. We called this process *inferential monitoring*. In addition, the electrophysiological results of Study 3 showed that all readers presented a larger P3a in the disambiguating word when they had previously read no update information (no update and neutral sentences) compared to when they read update information (update sentence). According to the context–updating theory (Polich, 2003, 2007) the P3a occurs when incoming information demands attentional control because is evaluated as 'new' or 'different' with respect the current memory representation. This meant that once more all readers detected an inconsistency between the inference primed in the introduction and the final unexpected concept, which was associated to the P3a subcomponent. Together these results demonstrate that adult readers are able to successfully monitor their inferential comprehension during on–line reading.

Furthermore, the results of Study 2 and 3 are in line with previous studies showing successful detection of actions that are inconsistent with a prior implicit character's goal (e.g., Poynor & Morris, 2003). However, rather than monitor information specifically about a character's action, our inferential monitoring (see Appendix C, p. 197) and situation model updating (see Appendix F, p. 215) tasks required to detect very varied inconsistencies about different *characters* (e.g., the neighbor of someone instead of the girlfriend; or a turtle instead of a frog), *things* (e.g., a swing instead of a slide; or an onion instead of a garlic), *places* (e.g., a library instead of a hospital; or a kitchen instead of a bathroom), and *actions* (e.g., paragliding instead of falling; or lying instead of suffering). This demonstrates that readers monitor their comprehension along a wide range of world knowledge information. Moreover, although we mainly explored the causality dimension, our results are congruent with models of comprehension defending that readers continuously monitor their mental representation along the dimensions of time, space, causality, motivation or intention, and agents (Magliano, et al., 1999; Therriault & Rinck, 2007; Zwaan & Radvansky, 1998). For example, the Event–Indexing model (e.g., Zwaan, et al., 1995) has empirically proved that when coherence breaks appear in one of the five dimensions readers experience difficulty shown by longer reading times. This means that readers are constantly keeping track of the character's temporal and spatial placements, their goals and intentions, the reasons of why they perform actions and the relationships that they establish with other characters.

Interestingly, the results of our Study 2 also showed a smaller number of correct responses to the critical sentences when inconsistent information was presented in the story. We interpreted this result as an inability of the readers to change the previous interpretation. Considering that reader's expectation was strongly facilitated by highly causal constraints, it could occur that they did not realise that the general context of the story had changed into something different. This idea is consistent with what has been called the illusion of knowing (Glenberg et al., 1982). That is, sometimes readers overestimate their understanding, and believe that they know what it has been expressed in the text. Furthermore, the illusion of knowing is connected to the illusion of explanatory depth, by which readers overestimate the detail and depth of their explanatory knowledge (Mills & Keil, 2004). Therefore, although we cannot know what really happened in the responses to the critical sentences, a possible reason is that readers were influenced by the explanatory arguments that they elaborated with the knowledge–based inference at the beginning of the narrative (strong semantic expectation) and thus, they erroneously thought that they knew the answer.

Besides the process to monitor inconsistent information, we also investigated the ability to repair an inconsistency by the replacement of prior no longer relevant activated information with new relevant information (updating). An example of updating is the revision process. Revision involves the encoding of new information, the detection of an inconsistency, and further the replacement of the outdate information with the new information (Rapp & Kendeou, 2007). The results of our Study 2 and 3 also bring important implications to the revision process of updating information. Specifically, in Study 2 we included a critical sentence (just below the narrative text) that was related to the target concept presented in the story. This sentence allowed us to observe 1) if readers benefited when prior consistent information (expected concept) had been presented, and 2) if readers updated their situation model when prior inconsistent information (unexpected concept) had been presented. In relation to the first goal, we observed that readers took shorter total times when the critical sentence was related to the expected information compared to when it was unrelated (congruent versus incongruent conditions). This result indicated that the expected concept was already activated in the mental representation facilitating the recognition of subsequent related information. Thus, when a prior highly constrained context biased an inference that was subsequently confirmed all readers were faster reading (and better answering) critical sentences that were related to that concept. In relation to the second goal, the Study 2 showed that readers took longer total times when the critical sentence was congruent with prior inconsistent information (e.g., '*playing cards*' after '*snap*') than when it was congruent with prior consistent information (e.g., '*moving pieces*' after '*chess*'). This effect was interpreted as a difficulty to update the situation model because the knowledge–based inference primed by the prior context was still active in memory. This is in line with studies finding that readers sometimes fail to discard the outdate information, even when new information is updated (e.g., Guéraud, et al., 2005; Hakala & O'Brien, 1995; Johnson & Seifert, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien, et al., 2010; O'Brien, et al., 1998; Rapp & Kendeou, 2007, 2009; van Oostendorp & Bonebakker, 1999). However, we also evaluated working memory capacity in order to see if there were individual differences in the ability to update the situation model.

In Study 2 the critical sentence was presented together with the narrative text in order to see if readers needed to reread the story to find the answer. According to this, we found that high span readers took shorter go–past times (less time rereading prior segments) than low span readers only when inconsistent information (unexpected concept) had been presented. This finding demonstrated that skilled memory readers are able to discard outdated information from their situation model, even if that information has been inferentially generated. On the contrary, less skilled memory readers seem to have difficulties discarding no longer relevant information from their mental representation and therefore, they experience problems to answer the critical sentences. Furthermore, these results are consistent with the electrophysiological findings of our Study 3. In the situation model updating task the critical information was followed by a final sentence that brought a disambiguating word. This word required 1) the detection of inconsistent information when no previous information signalled the update (neutral and no update sentences), and 2) similar to the critical sentence presented in Study 2, to confirm if prior inconsistent inferential information has been updated (update sentence). As we discussed before, the activation of a P3a potential was associated to the detection of the inconsistency indicating a successful monitoring of the inferential information. Moreover, we also found that readers with high working memory capacity presented a smaller P3b in the disambiguating word when they had read the prior update information compared to when they had not read any update information. Readers with low working memory did not show a reduction in the P3b. According to the context–updating theory (Polich, 2003, 2007) the P3b is generated when incoming information forces some attentional resources to favour context updating by memory operations. Therefore, our results demonstrated that the more skilled memory readers were able to benefit from the previous update information, while the less skilled memory readers did not. That is, high skilled memory readers are able to discard a previous wrong interpretation during on–line reading, inferentially updating the new information into the situation model. In contrast, low skilled memory readers do not seem to inferentially update their situation model.

The previous findings are consistent with studies demonstrating that poor comprehenders are also poor updaters on the contents of working memory (e.g., Carretti, et al., 2005; Palladino, et al., 2001). Thus, these differences in working memory capacity suggest the involvement of inhibitory processes in the ability to update the situation model whereby the suppression of the outdated information (see following section 4.4.). Moreover, it is important to notice that differently from studies providing explanations to the inconsistent information (e.g., Kendeou, et al., 2013; O'Brien et al., 1998; Rapp & Kendeou, 2007, 2009) our experimental task did not include further information that could help to solve the inconsistency. This result is interesting since it demonstrates that good updaters do not necessarily demand additional explanations. In addition, the distinction found between the P3a and P3b demonstrated an apparent dissociation between the process to monitor inconsistent information (top–down process), and the process to update information (bottom–up process).

Furthermore, unlike the Study 2, the Study 3 highlights the possibility that less skilled memory readers experienced more difficulty to update an inference with new inferential information (inferential updating process). This had to do with the results of the N400 potential: readers with high working memory manifested a larger N400 when no update information was provided (neutral and no update sentences) relative to when update information was presented (update sentence). This result demonstrated the better ability of skilled memory readers to detect a semantic incongruity between the incoming information and their no updated situation model. However, readers with low working memory did not show a differential pattern of activation after reading the no update and update information. This result suggested that less skilled readers were not able to detect the semantic incongruity between the new information and the prior inferred idea. Therefore, the N400 potential seems to indicate that skilled memory readers are able to inferentially update their situation model because they accurately represent the inferential information into working memory. In contrast, less skilled memory readers may have problems to update their situation model because they do not precisely define the inferential information, especially when this information is semantically similar. This is consistent with those studies reporting that semantic interference affects the ability to update the contents of working memory (e.g., Szmalec, et al., 2011).

To sum up, the results of our Study 2 and 3 highlight important implications to the cognitive processes of comprehension monitoring and updating information. On the one hand, readers are able to monitor inferential information detecting inconsistencies between text information and their mental representation. This occurs with multiple types of inconsistent information such as characters, things, places and actions. In addition, although readers detect the inconsistencies, sometimes they fail to correctly answer what was the text about. This has been connected to the effects of illusion of knowing (Glenberg et al., 1982) and illusion of explanatory depth (Mills & Keil, 2004). On the other hand, readers differ in their ability to update information. Skilled memory readers successfully update their situation model discarding outdated information, even when this information is inferential. On the contrary, less skilled memory readers seem to have difficulties discarding no longer relevant information, which suggests deficits in inhibitory processes (see section 4.4.). Accordingly, we have demonstrated a clear dissociation between a top–down process of monitoring inconsistencies (reflected in the P3a potential), and a bottom–up process of updating information (manifested in the P3b potential). Finally, we suggest the possibility that, especially when information is semantically similar, less skilled memory readers may have problems updating information because they do not accurately represent inferential information into their memory representation (reflected in the N400 potential). In the following section, we describe the implications of our results to working memory capacity.

4.4. IMPLICATIONS FOR WORKING MEMORY CAPACITY

The capacity to actively represent concepts, maintain critical ideas and process changes and complex information in working memory is fundamental for language and reading comprehension (e.g., Carretti, et al., 2009; Daneman &

Merikle, 1996; Just & Carpenter, 1992). In addition, working memory enables access to prior knowledge stored in long–term memory, whereby related information is retrieved in order to provide coherence to the situation model. Thus, many high–level cognitive processes may rely on working memory. The results of our three experimental studies have implications about the influence that exerts working memory capacity in the processes of inference making, comprehension monitoring and updating information.

In Study 1 (Pérez, et al., 2014) we investigated the role of working memory capacity in inferential sentence comprehension. As we mentioned before, we used a categorization distinguishing between explicative, predictive and associative inferences (Trabasso & Magliano, 1996). In contrast to the simple retrieval of prior knowledge required by associative inferences, explicative and predictive inferences additionally require connection between several sentences across the text by means of causal (antecedent or consequent) relationships. Therefore, we predicted a stronger influence of working memory in those comprehension sentences that required causal connections to generate the inference. The results of Study 1 demonstrated that only comprehension sentences based on explicative and predictive inferences were associated with individual differences in working memory: low working memory readers showed a smaller number of correct responses in the explicative sentences and took longer in the predictive sentences compare to high verbal working memory readers. In addition, no working memory differences were found in the associative and verbatim sentences. Considering that the paragraph was not available when the sentences were presented to the participants, these results were interpreted as either poor ability of low working memory readers and/or good ability of high working memory readers to actively maintain the causal referent from text information. This is consistent with studies indicating that individuals with low working memory span are poorer at maintaining information than individuals with high memory span (e.g., Engle & Kane, 2004; Unsworth & Engle, 2007), and studies demonstrating a relationship between working memory and inference making (e.g., Barreyro, et al., 2012; Chrysochoou, et al., 2011; Daneman & Green, 1986; Friedman & Miyake, 2000; St. George, et al., 1997; Singer, et al., 1992; Virtue, et al., 2006; Whitney, et al., 1991).

Therefore, knowledge–based inferences demanding the connection of current text information to a causal antecedent (explanations) or a possible causal consequence (predictions) depend on the ability to maintain critical contents in working memory capacity. On the contrary, knowledge–based inferences that only require the connection of focal information with background knowledge (associations) are not necessarily affected by the active maintenance of critical information in working memory capacity. Interestingly, the results of Study 1 can be also interpreted as that low working memory readers are likely to activate more irrelevant information than high working memory readers, which could led to both less accurate and slower recall. Studies 2 and 3 shed some light into this question and the role of working memory in comprehension monitoring and updating information processes.

In relation to comprehension monitoring, both Study 2 and 3 showed that longer reading times associated with the detection of inconsistent information (unexpected and update conditions) were not explained by working memory differences, even though this information was inferential (inferential monitoring). This is in line with the literature, since not many studies have informed about working memory differences in the ability to monitor comprehension in adults (e.g., Daneman & Carpenter, 1983; Schommer & Surber, 1986). For example, De Beni, et al. (2007) demonstrated that working memory differences and self–monitoring metacomprehension were associated to problems of narrative comprehension only in old–old adults (75–85 years) but not in young adults (18–30 years) or young–old adults (65–74 years). Therefore, the ability to monitor inconsistencies in normal adults does not seem to be affected (or just in a very few level) by individual differences in working memory. However, an interesting pattern related to comprehension monitoring appeared in our eye–movements experiment: low span readers did more regressions from the critical concept (expected or unexpected) to the prior context of the text than high span readers. Thus, although all readers were able to successfully monitor their comprehension (inconsistency detection), low working memory readers needed to reread the general context of the story after reading the critical information. We believe this was because low working memory readers had difficulties integrating the critical (consistent or inconsistent) information with prior context. In contrast, high working memory readers did not need to reread the introductory sentences, suggesting that they were able to integrate incoming information into a coherent situation model. According to Daneman and Carpenter (1983) less efficient readers allocate so much capacity to processing the incoming words that they may be less likely to have the previous relevant information still available in working memory or be less able to retrieve it from long–term memory. Therefore, although low working memory readers are able to use the context to generate the appropriate inference, they have poorer access to the information that supports this inference.

In relation to updating information, both Study 2 and 3 demonstrated individual differences in working memory capacity. As we mentioned in the previous section, 1) in Study 2 high span readers took shorter go–past times (this is, they spent less time rereading previous information) in the critical sentence than low span readers only when inconsistent information (unexpected concept) had been presented; and 2) in Study 3 high span readers benefitted from the presentation of prior update information (smaller P3b), while low span readers did not show this facilitation (no differences between conditions in the P3b). These results were interpreted as the better ability of high working memory readers to discard outdated information from their situation model during on–line reading. Conversely, low working memory readers have problems to discard no longer relevant information, failing to update their situation model. Furthermore, we have suggested the possibility that differences in working memory capacity may be reflecting differences in inhibitory processes. In relation to this, the Structure–Building model (Gernsbacher, 1990, 1997) proposes that less skilled readers have difficulties integrating new information into the mental representation because they are unable to suppress no longer relevant information (e.g., Gernsbacher & Faust, 1991). This interpretation fit perfectly with our results: low working memory readers are less able to update their situation model because they fail to suppress the outdated information. In fact, this interpretation is congruent with studies demonstrating that individuals with low working memory capacity have deficits in inhibitory control related to poor reading comprehension (Barnes, et al., 2004; De Beni, et al., 1998; Pimperton & Nation, 2010). Therefore, working memory individual differences in the ability to update information into the situation model can be explained by differences in inhibitory processes necessary to suppress the information that must be replaced. Importantly, in Study 2 we tested whether differences in the way in which readers update their mental representation were explained by the verbal domain of working memory. To do so, we evaluated working memory measures for both the verbal domain (listening recall and backward digits recall tasks) and the visuospatial domain (odd one out and spatial recall tasks). The results demonstrated that individual differences in the ability to update the situation model were specifically associated with the verbal working memory. In fact, no results were found between the updating process and the visuospatial working memory. Then, we concluded that the process to update information in reading comprehension depends only and exclusively on the verbal domain of working memory. This is consistent with studies showing a relationship between listening/reading comprehension and the involvement of the verbal domain (e.g., Caplan & Waters, 1999; Nation, et al., 1999; Seigneuric, et al., 2000); and more importantly, this specificity of the verbal domain has been also associated to deficits in inhibitory processes to suppress irrelevant information (Pimperton & Nation, 2010). Therefore, although previous findings of individual differences in updating information has been related to the central executive (e.g., Carretti et al., 2005; Morris & Jones, 1990; Palladino, et al., 2001), our results demonstrate that these inferences are exclusively related to the verbal domain with few or no influence of visuospatial working memory.

Finally, our electrophysiological results about the N400 potential in Study 3 also reflected individual differences: high working memory readers showed a larger N400 when prior sentence did not provide updating information compared to when it was provided, while low working memory readers did not manifest that difference. Since the N400 has been commonly interpreted as the detection of semantic incongruence, these findings were explained as 1) a good ability of high working memory readers to clearly identify the critical inferential concept of the story, updating the situation model; and/or 2) a poor ability of low working memory readers to accurately represent the critical inferential concept, failing to update the situation model. These interpretations were supported by the issue that both possible concepts in Study 3 shared important semantic similarities that could cause semantic interference in less skilled memory readers.

To sum up, our findings about the role of working memory capacity in high–level cognitive processes indicate a differential pattern according to the specific process. In relation to this, individual differences in working memory predict the ability to make causal inferences such as explicative or predictive. This is explained by the ability to maintain critical information (as the causal referent) in working memory. On the contrary, the ability to monitor inferential inconsistencies does not seem to depend on working memory differences, although low working memory readers may have problems to integrate new information with prior segments in the text. Moreover, individual differences in working memory are apparent in the ability to update information into the situation model. These results suggest that low working memory readers have problems updating their mental representation because they fail to suppress the outdated information, while high working memory readers are able to suppress no longer relevant information, successfully updating their situation model. Finally, these individual differences in the updating process are exclusively associated to the verbal domain of working memory, with no influence of the visuospatial domain.

4.5. FINAL CONCLUSIONS

According to the general aim of this thesis, we have studied how several high–level cognitive processes underlie the construction of the situation model and how these processes are related to working memory. Specifically, we have demonstrated that only some knowledge–based inferences requiring the connection between the current information and prior segments of the text (explicative inferences) or possible future outcomes (predictive inferences) are influenced by the ability to maintain information in working memory when answering off–line comprehension sentences. We propose that this is due to their causal nature, since they require the active maintenance of not just the current information but also the causal referent (antecedent or consequent) to which is associated. Additionally, we have shown how highly constrained contexts bias knowledge–based inferences that are encoded during on–line reading. Moreover, adults commonly monitor their comprehension: they are able to detect text information that is inconsistent with their current situation model. This result has been associated to the P3a potential in ERPs, and it is not explained by individual differences in working memory, although less skilled memory readers may have problems integrating new information with prior parts of the text. Interestingly, beyond the detection of inconsistencies, the presence of inconsistent information in a text means that sometimes readers fail to provide a correct answer about the story, even when the text is still presented. This effect may be related to the illusion of knowing (Glenberg et al., 1982) and/or the illusion of explanatory depth (Mills & Keil, 2004), by which readers overestimate their understanding of the story. More importantly, the ability to update information into the situation model depends on working memory capacity: high working memory readers update their mental representation during on–line reading; in contrast, low working memory have difficulties updating their mental representation, which suggests the idea of deficits in inhibitory processes to suppress the outdated information. These results seem to be specifically restricted to the verbal domain of working memory with no influence of the visuospatial domain. Furthermore, working memory differences found in updating has been associated to the P3b potential. This highlights an apparent dissociation between a top–down process of monitoring inconsistencies (P3a potential), and a bottom–up process of updating information (P3b potential). Finally, the inferential updating process suggests that low working memory readers could also have problems accurately representing inferential information into their situation model. This has been related to the N400 potential and would especially occur when readers have to update inferential information that is semantically similar.

With these findings we hope to have shed some light to the complex ability of text comprehension. It is important to notice that most of readers participating in the experimental studies of this thesis were undergraduate students (Spanish or English), which are usually considered to have a very high–level of comprehension. Thus, it would be not surprising to find larger differences in less literate adults or children. From our point of view, there is a growing need for designing and implementing efficient programs to train high cognitive processes involved in the construction of the situation model. For example, strengthening the causal reasoning in inference making; facilitating questions to monitor readers' comprehension; or requiring them to provide arguments of why something has changed in the story, to improve their ability to update information. Furthermore, it would be essential to train verbal working memory capacity for example by the maintenance of critical information, the retrieval of appropriate prior knowledge, or the suppression of no longer relevant ideas that have been modified. Ideally, these training programs should be designed for children to prevent comprehension problems from early ages and improve understanding and cognition in general.

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6. APPENDICES

APPENDIX A. Essay of reading with original version (in Spanish).

Querido lector, imagínese que ha decidido tomarse una tarde de domingo para leer un poco de narrativa adulta. Desde la estantería de casa coge ese libro de Julio Cortázar que le regaló un amigo hace ya varios meses y lee "Final del juego". Al abrir la tapa, el título del primer cuento le inspira y comienza a leerlo:

"*Había empezado a leer la novela unos días antes. La abandonó por negocios urgentes, volvió a abrirla cuando regresaba en tren a la finca; se dejaba interesar lentamente por la trama, por el dibujo de los personajes. Esa tarde, después de escribir una carta a su apoderado y discutir con el mayordomo una cuestión de aparcerías, volvió al libro en la tranquilidad del estudio que miraba hacia el parque de los robles. Arrellanado en su sillón favorito, de espaldas a la puerta que lo hubiera molestado como una irritante posibilidad de intrusiones, dejó que su mano izquierda acariciara una y otra vez el terciopelo verde y se puso a leer los últimos capítulos. Su memoria retenía sin esfuerzo los nombres y las imágenes de los protagonistas; la ilusión novelesca lo ganó casi enseguida… Primero entraba la mujer, recelosa; ahora llegaba el amante, lastimada la cara por el chicotazo de una rama. Admirablemente restañaba ella la sangre con sus besos, pero él rechazaba las caricias, no había venido para repetir las ceremonias de una pasión secreta, protegida por un mundo de hojas secas y senderos furtivos. El puñal se entibiaba contra su pecho, y debajo latía la libertad agazapada. Un diálogo anhelante corría por las páginas como un arroyo de serpientes, y se sentía que todo estaba decidido desde siempre. Hasta esas caricias que enredaban el cuerpo del amante como queriendo retenerlo y disuadirlo, dibujaban abominablemente la figura de otro cuerpo que era necesario destruir…*"

Si se detiene un segundo para preguntarse ¿quién tiene el puñal en la historia y a quién quiere matar?, probablemente infiera correctamente que se trata del amante de la mujer, y que juntos han acordado matar al marido de ella. No obstante, si continúa leyendo:

"*Sin mirarse ya, atados rígidamente a la tarea que los esperaba, se separaron en la puerta de la cabaña. Ella debía seguir por la senda que iba al norte. Desde la senda opuesta él se volvió un instante para verla correr con el pelo suelto. Corrió a su vez, parapetándose en los árboles y los setos, hasta distinguir en la bruma malva del crepúsculo la alameda que llevaba a la casa. Los perros no debían ladrar, y no ladraron. El mayordomo no estaría a esa hora, y no estaba. Subió los tres peldaños del porche y entró. Desde la sangre galopando en sus oídos le llegaban las palabras de la mujer: primero una sala azul, después una galería, una escalera alfombrada. En lo alto, dos puertas. Nadie en la primera habitación, nadie en la segunda. La puerta del salón, y* *entonces el puñal en la mano, la luz de los ventanales, el alto respaldo de un sillón de terciopelo verde, la cabeza del hombre en el sillón leyendo una novela.*" (Cortázar, 1994)

Y ahora ¿a quién mata el amante, y en qué plano se desarrolla la historia? Sólo si el lector ha mantenido en su memoria la información que se describe al principio del cuento, será capaz de entender que el marido al que quieren matar los amantes es el propio personaje de la historia, el cual lee la novela. El cambio de perspectiva desde el libro que lee el personaje al libro que lee usted, conlleva una actualización del plano donde se desarrolla la historia, y consecuentemente fuerza una nueva reinterpretación de lo que se ha leído.

El ensayo anterior sirve para ejemplificar la complejidad que entrañan algunos procesos cognitivos en la comprensión de textos, tales como la habilidad para extraer información que no se menciona explícitamente, la capacidad de mantener información en memoria y recuperarla, así como la habilidad para sustituir una interpretación errónea por una nueva más probable. Todos estos procesos son necesarios para crear una representación mental del texto que sea coherente, precisa y certera, de lo que se deduce la gran cantidad de recursos que se ponen en juego durante la lectura de un texto.

(Continúe leyendo en el apartado 1.1., pág. 4).

APPENDIX B. Inferential task used with comprehension sentences (Study 1)

Narrative 1

Un día llegó un grupo de hombres pálidos a nuestra aldea. Cazadores con pólvora, desde lejos, sin destreza ni valor, eran incapaces de trepar a un árbol o de clavar un pez con una lanza en el agua, apenas podían moverse en la selva, siempre enredados en sus mochilas, sus armas y hasta sus propios pies. No se vestían de aire, como nosotros, sino que tenían unas ropas empapadas y hediondas, eran sucios y no conocían las reglas de la decencia, pero estaban empeñados en hablarnos de sus conocimientos y de sus dioses. Los comparábamos con lo que nos habían contado sobre los blancos y comprobamos la verdad de esos chismes. Pronto nos enteramos que éstos no eran misioneros, soldados ni recolectores de caucho, estaban locos, querían la tierra y llevarse la madera, también buscaban piedras. Les explicamos que la selva no se puede cargar a la espalda y transportar como un pájaro muerto, pero no quisieron escuchar razones.

- E1[1]- Los hombres pálidos eran cobardes porque cazaban con pólvora.
- E2- Los hombres pálidos eran valientes porque cazaban con pólvora.
- A1- Los cazadores eran torpes al andar por el uso de calzado.
- A2- Los cazadores eran ágiles al andar por el uso de calzado.
- V1- Los hombres pálidos hablaban de sus dioses.
- V2- Los hombres pálidos hablaban de sus antepasados.
- P1- Los cazadores pretendían comerciar con las piedras que encontrasen.
- P2- Los cazadores pretendían hacer un fuego con las piedras que encontrasen.

Se instalaron cerca de nuestra aldea. Cada uno de ellos era como un viento de catástrofe, destruía a su paso todo lo que tocaba, dejaba un rastro de desperdicio, molestaba a los animales y a las personas. Al principio cumplimos con las reglas de cortesía y les dimos el gusto, porque eran nuestros huéspedes, pero ellos no estaban satisfechos con nada, siempre querían más, hasta que, cansados de esos juegos, iniciamos la guerra con todas las ceremonias habituales. No son buenos guerreros, se asustan con facilidad y tienen los huesos blandos. No resistieron los garrotazos que les dimos en la cabeza.

- P1- La práctica alimenticia de los cazadores estaría basada en un consumo irresponsable, irrespetuoso con los animales.
- P2- La práctica alimenticia de los cazadores estaría basada en un consumo responsable, respetuoso con los animales.
- V1- Los hombres pálidos fueron considerados como huéspedes.
- V2- Los hombres pálidos fueron considerados como dioses.
- E1- La guerra se desencadena por la ambición de los hombres pálidos.
- E2- La guerra se desencadena por la motivación de los hombres pálidos.
- A1- Los hombres pálidos tienen los huesos blandos por su falta de resistencia física.
- A2- Los hombres pálidos tienen los huesos blandos por su falta de resistencia emocional.

Después de eso abandonamos la aldea y nos fuimos hacia el este, donde el bosque es impenetrable, viajando por las copas de los árboles para que no nos alcanzaran sus compañeros. Nos había llegado la noticia de que son vengativos y que por cada uno de ellos que muere, aunque sea en una batalla limpia, son capaces de eliminar a una tribu incluyendo a los niños. Descubrimos

[1] Las frases de comprensión siempre aparecieron sin el párrafo (off–line). El orden de presentación fue el que aquí se refleja, donde E = explicativa; A = asociativa; V = verbatim o literal; P = predictiva, y siempre en una de las dos versiones: 1 = verdadera; o 2 = falsa.

un lugar donde establecer otra aldea. No era tan bueno, las mujeres debían caminar horas para buscar agua limpia, pero allí nos quedamos porque creímos que nadie nos buscaría tan lejos.

- A1- Al viajar por las copas de los árboles los cazadores tenían mayor dificultad para detectarlos.
- A2- Al viajar por las copas de los árboles los cazadores tenían mayor facilidad para detectarlos.
- P1- Ser encontrados por los hombres pálidos significaba la exterminación de la tribu.
- P2- Ser encontrados por los hombres pálidos significaba la salvación de la tribu.
- E2- El nuevo asentamiento no resultaba tan apropiado por la lejanía de otras tribus.
- E1- El nuevo asentamiento no resultaba tan apropiado por la falta de agua potable.
- V1- Finalmente la tribu decide asentarse en el lugar encontrado.
- V2- Finalmente la tribu decide marcharse del lugar encontrado.

Al cabo de un año, en una ocasión en que tuve que alejarme mucho siguiendo la pista de un puma, me acerqué demasiado a un campamento de soldados. Yo estaba fatigado y no había comido en varios días, por eso mi entendimiento estaba aturdido. En vez de dar media vuelta cuando percibí la presencia de los soldados extranjeros, me eché a descansar. Me cogieron los soldados. Sin embargo, no mencionaron los garrotazos propinados a los otros, en realidad no me preguntaron nada. Me llevaron a trabajar con los caucheros, donde había muchos hombres de otras tribus, a quienes habían vestido con pantalones y obligaban a trabajar, sin considerar para nada sus deseos.

- V1- El hambre del indígena le impidió pensar con claridad.
- V2- El odio del indígena le impidió pensar con claridad.
- E1- Los soldados no comentaron nada de los garrotazos porque no sabían nada del suceso.
- E2- Los soldados no comentaron nada de los garrotazos para no perder tiempo.
- P1- Los soldados querían tanto caucho para comercializar con él fuera de la aldea.
- P2- Los soldados querían tanto caucho para sobrevivir con él en la aldea.
- A1- Los caucheros tenían unas condiciones de trabajo de esclavitud.
- A2- Los caucheros tenían unas condiciones de trabajo legales.

Narrative 2

Archibald iba muy seguido al barrio mexicano de Chicago porque su bufete defendía muchos casos de comerciantes, naturalizaciones, gente sin tarjeta verde, los mil asuntos relacionados con la inmigración y el trabajo llegados del sur de la frontera... Iba, además, porque permanecía soltero a los cuarenta y dos años, convencido de que antes de casarse tenía que beber hasta las heces la copa de la vida, sin ataduras de familia, hijos, mujer...

- A1- Archibal era abogado.
- A2- Archibald era comerciante.
- P1- La gente sin tarjeta verde tendría condiciones laborales ilegales.
- P2- La gente sin tarjeta verde tendría condiciones laborales con contrato.
- E1- La inmigración que atendía Archibald provenía de México.
- E2- La inmigración que atendía Archibald provenía de China.
- V1- Archibald permanecía soltero a los cuarenta y dos años.
- V2- Archibald permanecía soltero a los cincuenta y dos años.

Por ser Chicago una ciudad donde se cruzaban tantas culturas, el singular Archibald iba escogiendo sus novias por zonas étnicas. Ya había agotado los barrios ucraniano, polaco, chino, húngaro y lituano. Ahora la feliz conjunción de su trabajo y la curiosidad amatoria lo habían traído a Pilsen, el barrio mexicano con nombre checo, el nombre de la ciudad cervecera de la Bohemia. Los checos se habían ido y los mexicanos lo fueron ocupando poco a poco, llenándolo de mercados, loncherías, música, colores, centros culturales y, desde luego, cerveza tan buena como la de Pilsen.

- A1- El país donde estaba Archibal era EEUU.
- A2- El país donde estaba Archibal era Bohemia.
- E1- El barrio mexicano se llamaba Pilsen porque había estado ocupado por los checos.
- E2- El barrio mexicano se llamaba Pilsen porque bebían cerveza tan buena como la checa.
- V1- Los mexicanos llenaron el barrio de mercados y loncherías.
- V2- Los checos llenaron el barrio de mercados y loncherías.
- P1- La lengua materna de un habitante del barrio probablemente sería español.
- P2- La lengua materna de un habitante del barrio probablemente sería americano.

Muchos vinieron a trabajar a las empacadoras, algunos documentados, otros no, pero todos sumamente apreciados por su habilidad manual en cortar y empacar la carne. El abogado, Archibald, se hizo novio de una de las muchachas de la gran familia formada por los trabajadores, casi todos provenientes de Guerrero, todos ellos ligados entre sí por parentesco, solidaridad y a veces nombres compartidos.

- P1- Posiblemente, muchos de los mexicanos regresarían a México después de trabajar durante años.
- P2- Posiblemente, muchos de los mexicanos derrocharían el dinero después de trabajar durante años.
- V1- Muchos trabajadores estaban en las empacadoras.
- V2- Muchos trabajadores estaban en las joyerías.
- E1- La familia de la actual novia de Archibald era apreciada por su habilidad manual en cortar y empacar la carne.
- E2- La familia de la actual novia de Archibald era despreciada por su habilidad manual en cortar y empacar la carne.
- A1- La actual novia de Archibald era Guerrero.
- A2- La actual novia de Archibald era de la región.

Se ayudaban mucho, eran como una gran familia, organizaban fiestas y como todas las familias, reñían. Una noche, hubo pleitos y dos muertos. La policía no se anduvo por las ramas. Los asesinos eran cuatro, uno de ellos se llamaba Pérez, tomaron a cuatro Pérez, los acusaron, ellos casi no hablaban inglés, no se pudieron explicar, no entendieron las acusaciones, y uno de ellos, al que Archibald fue a visitar a la cárcel, le explicó que la acusación era injusta, se basaba en testimonios falsos para proteger a los verdaderos asesinos, se trataba de encubrir cuanto antes a los sospechosos y cerrar cuanto antes el expediente, ellos no se sabían defender. Archibald tomó el caso y así conoció a la mujer del acusado que Archibald visitó en la cárcel. Se llamaba Josefina, se acababan de casar, ya era tiempo, tenían cuarenta años cada uno, Josefina hablaba inglés porque descendía de un trabajador del acero, Fortunato Ayala, que la tuvo y abandonó en Chicago, pero estaba en México cuando ocurrieron los hechos y no pudo socorrer a su marido.

- V1- Los asesinos eran cuatro, uno de ellos se llamaba Pérez.
- V2- Los asesinos eran tres, uno de ellos se llamaba Pérez.
- E1- Alguien explicó que la acusación era injusta porque se pretendía encubrir a los verdaderos asesinos bajo su incapacidad para defenderse hablando inglés.
- E2- Alguien explicó que la acusación era injusta porque se pretendía encubrir a los
- P1- Si Josefina hubiese estado en Chicago probablemente hubiese socorrido a su marido.
- verdaderos asesinos gracias a su capacidad para defenderse hablando inglés.
- P2- Si Josefina hubiese estado en Chicago probablemente se hubiese mantenido al margen de la acusación.
- A1- Fortunato Ayala era el padre de Josefina, la mujer del acusado.
- A2- Fortunato Ayala era el acusado, el marido de Josefina.

APPENDIX C. Inferential monitoring task used with eye movements (Study 2)

Practice

a) It was the 60s and a revolutionary thought movement had already started. Begonia and her friends let their hair grow really long, and they had flowers all over their clothes. Hippies were campaigning for the triumph of human *peace* over all.

   - Hippies were demonstrating *against the war*. [Yes]

b) Every morning Nicole likes to have fresh fruit for breakfast. Although she has many different kinds at home, Nicole has preference for small red round fruit. Today for example, she put two slices of *tomato* in her bowl.

   - Nicole likes to have a bowl of *cereal* for breakfast. [No]

c) The sounds of the pot roared from the kitchen, where my boyfriend had been cooking the whole morning. After a few minutes, a strong smell of burning came into my nose. I went into the kitchen and I saw the *apron* was on fire.

   - In the kitchen the *food* was on fire. [No]

d) Mark and Eve had recently moved in together. Although Eve was very busy with work, they were excitedly thinking of starting a family. Mark looked at baby clothes in a shop window, and he smiled hoping that Eve would get *pregnant* as soon as possible.

   - Mark was hoping that Eve might have a *baby* soon. [Yes]

Experimental texts

1. They were going to show a horror film at the local cinema. In the review, Christine had read that the film was about a vampire that killed lots of people. During the film Christine realized that the vampire would die if he did not drink *blood/broth* every night.

   - In the film, the vampire had to drink *a bodily fluid* to survive.
   - In the film, the vampire had to drink *seasoned soup* to survive[1].

2. My neighbour is obsessed with her garden. She can spend hours and hours planting seeds or pruning roses. Yesterday she switched on the sprinkler, and watered the *grass/hedge* the whole day.

   - Yesterday, my neighbour watered her *lawn* with the sprinkler.
   - Yesterday, my neighbour watered her *privet* with the sprinkler.

3. The documentary was about how famine in the 'Third World' was getting worse. In southern Africa especially, the incidence of malnutrition has increased hugely over the last few years. A young boy was crying because of the shortage of *food/games* in his house.

   - The young boy didn't have many things to *eat* in his house.
   - The young boy didn't have many things to *play with* in his house.

[1] Participants read either the expected ('*blood*') or unexpected ('*broth*') concept in the main text, and the congruent or incongruent words with the prior concept in the critical sentence. They had to answer '*Yes*' if it was congruent, or '*No*' if it was incongruent.

4. The Muslim family was having problems integrating into the new society. For example, little Eylem's first day of school, was very stressful for her. The other children were mean and pointed at her *headscarf/hairband* decorated with bright beads.

   - Eylem had *covered her head* to go to the school.
   - Eylem had *put her hair up* to go to the school.

5. This morning Sarah's son woke up complaining of a bad headache. His mother knew what to do, so she made a phone call and helped her son to get into the car. After parking the car, Sarah guided her son to the *doctor/school* through the main door.

   - This morning Sarah's son was *feeling very* ill.
   - This morning Sarah's son was *pretending to be* ill.

6. The father was reading a fairy tale to Susie and Tom. On each page, the children looked at the pictures and asked questions about the story. The main character of a story was a witch who had escaped, and Tom asked why she was using a *broom/horse* to get away.

   - Tom was wondering why the main character needed *a stick* to get away.
   - Tom was wondering why the main character needed *an animal* to get away.

7. At the end of the tournament, the last two players were concentrating hard at each end of the table. Both of them were taking a long time to make a decision. After an hour and a half the *chess/snap* game was finished.

   - The players were *moving pieces* to win the tournament.
   - The players were *playing cards* to win the tournament.

8. In the river in my village there is a huge variety of plants and animals. Sometimes you can hear the croaking really loudly. Last Tuesday it was very noisy and I could even see a *frog/turtle* standing on a water lily.

   - There was an animal similar to a *toad* standing on the water lily.
   - There was an animal similar to a *tortoise* standing on the water lily.

9. It was already 25th of December and Sophie was back home. As a special treat, her father was making her a traditional Christmas dinner. The turkey was cooking, and it needed another hour in the *oven/grill* before it was done.

   - The turkey needed to be *roasted* for one more hour.
   - The turkey needed to be *barbecued* for one more hour.

10. Samuel is a petty thief. He is currently serving a three month prison sentence. A month ago, he was caught robbing a shop, from where he had stolen a lot of *cash/pizza* in just a few seconds.

   - Samuel was caught robbing a lot of *money* from a shop.
   - Samuel was caught robbing a lot of *food* from a shop.

11. The baby used to cry very often. His father thought how easy it would be if his wife were there to breastfeed the child, but she was at work. He took the feeding bottle and gave the *milk/water* to the desperate baby.

   - The father gave the *dairy* drink to his baby.
   - The father gave the *clear* drink to his baby.

12. At the dentist's surgery, I took one of the cheap magazines from the table. One page was talking about the royal wedding of some remote country. The bride had worn an incredible wedding dress, and on her head she had a *tiara/bonnet* which took everyone's breath away.

   - The bride stood out because of the *crown* in her head.
   - The bride stood out because of the *sunhat* in her head.

13. As she did every afternoon, the swimmer went to the swimming pool. Once in the water, she realised that she didn't have anything to help her to see under water. She got out of the pool, and drove home expecting to find her *goggles/glasses* case there.

    - The swimmer was looking for her *swimming* case, so she drove home.
    - The swimmer was looking for her *spectacles* case, so she drove home.

14. Ethan played an instrument in a Jazz band. He really admired Louis Armstrong and tried to imitate his characteristic inflated cheeks movement. Ethan could pass hours playing his *trumpet/violin* in front of the mirror.

    - Ethan had a *wind* instrument.
    - Ethan had a *string* instrument.

15. Kathie was visiting the ancient Greek museum of Athens. She had been studying the proportions of the human body, and now she could appreciate these marble works of art. Kathie was very impressed by one *sculpture/painting* placed in the first corridor.

    - Kathie was impressed by a *three-dimensional figure* in a corridor.
    - Kathie was impressed by a *two-dimensional picture* in a corridor.

16. Global Warming is bringing about irreparable damage to our ecosystem. In the North Pole for example, the reduction of icebergs is resulting in the death of many animals. The other day I saw on TV a *polar bear/sea lion* isolated in the melt water.

    - The TV shown the image of a *white* animal in the melt water.
    - The TV shown the image of a *grey* animal in the melt water.

17. Our office party this year had a Wild West theme. All my colleagues were really imaginative and dressed up as really silly things like a cactus or a horse. Robert was the simplest with just a cowboy hat on his head and a pair of *boots/trainers* on his feet.

    - Robert was dressed up simply with *cowboy footwear* and a hat on the head.
    - Robert was dressed up simply with *sports shoes* and a hat on the head.

18. The tectonic plates of the Earth are still active. Our teacher explained that especially in volcanic areas, the crash between these plates can cause huge catastrophes. We also learnt that this is due to the leak of *lava/smoke* onto the earth's surface.

    - The *dense and hot liquid* of volcano's eruptions can cause disasters.
    - The *gaseous and dark fumes* of volcano's eruptions can cause disasters.

19. Most evenings the traditional Scotsman played his bagpipes up on the hill. As he did so, he thought of his ancestors and their traditions. That night the wind was blowing fiercely and his legs had goose bumps from wearing his *kilt/coat* with nothing underneath.

    - The Scotsman wore *a traditional skirt* with nothing underneath.
    - The Scotsman wore *an outdoor jacket* with nothing underneath.

20. Ernest is the oldest librarian in my city. Everyone believes that he is the wisest man in the area because he used to read all the time, and has an impressive knowledge of the world. He must have a huge collection of *books/photos* from which he learnt.

    - Ernest must have a huge collection of *literature* from which he learnt.
    - Ernest must have a huge collection of *pictures* from which he learnt.

21. The mountain ride was difficult from the beginning. The well-known competitor started to sweat profusely as he was going uphill among the sharp rocks. With the rain, the stony ground caused the wheel of his *bicycle/scooter* to be punctured.

    - The competitor was working flat out while he *pedalled* uphill.
    - The competitor was working flat out while he *accelerated* uphill.

22. Aggie started to play basketball two weeks ago, and now she trains with her team every week. During a recent match she caught the ball and positioned herself. The crowd applauded as Aggie flung the ball through the *hoop/goal* with a smile in her face.

   - The crowd applauded as Aggie *threw* the ball towards its destination.
   - The crowd applauded as Aggie *kicked* the ball towards its destination.

23. The builder knew only too well how risky it was to work under the rubble. A few days ago a large stone fell from a wall directly onto his head. Fortunately, he was always well protected and the *helmet/harness* saved his life.

   - The builder's *skull* was protected.
   - The builder's *body* was protected.

24. The Mexican Carlos was having lunch. He was a guitar player in a Mariachi band, so he loved to dress in his typical costume with its fantastic big cap. Now he was having his favourite meal, a tasty burrito with *chilli/pesto* sauce.

   - The Mexican Carlos was eating a burrito with a *spicy* sauce.
   - The Mexican Carlos was eating a burrito with a *basil* sauce.

25. Europe has many important historic buildings recognized as World Heritage. My aunt told me that the Roman Empire made a great contribution with their amphitheatres and circuses. In the city of Rome for example, the *Coliseum/Vatican* has incredible dimensions.

   - One World Heritage building was used for *gladiatorial contests* mainly.
   - One World Heritage building is used for *religious reasons* mainly.

26. There were just a few people in the audience. The music was already playing when the dancer turned up. Even the barman stopped his work to see the wonderful movements of the *ballerina/actress* under the spotlight.

   - The woman was *dancing ballet* on the stage.
   - The woman was *playing a role* on the stage.

27. The supermarket was packed with people. The young Italian was wondering what to cook for dinner to impress his new flatmates. He got some parmesan and now he just needed a big packet of *pasta/lentils* and he'd be ready.

   - The young boy was planning to cook *an Italian dish* for his flatmates.
   - The young boy was planning to cook *a pulse stew* for his flatmates.

28. Julie was always in a rush because her career as a stewardess demanded that she be constantly travelling. Today she was supposed to travel to Istanbul. Unfortunately this time she was late for the *plane/taxi,* so she couldn't travel.

   - Julie didn't get *to the airport on* time, so she couldn't travel.
   - Julie didn't get *the minicab in* time, so she couldn't travel.

29. This is my favourite season: spring. I love it because everything is in bloom and it is colourful everywhere. Today something also appeared in my flowerpot: some tiny little *shoots/worms* have grown.

   - Today some *green leaves* have grown in the plant pot.
   - Today some *brown creatures* have grown in the plant pot.

30. Hard-working Daniel brought his homework back from school. He was learning how to draw and colour different kinds of figures, and how to cut them out. This time he drew a yellow tractor and cut out the shape with the heavy *scissors/knives* made of metal.

   - Daniel had to *snip the paper* to remove the drawing of the tractor.
   - Daniel had to *use the blade* to remove the drawing of the tractor.

APPENDIX D. Justified-by-the-design optimal random slopes, and model comparison to select the best random structure.

M1 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**participant), REML=TRUE)
M2 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**participant), REML=TRUE)
M3 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**participant), REML=TRUE)
M4 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**participant), REML=TRUE)
M5 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**item), REML=TRUE)
M6 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**item), REML=TRUE)
M7 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**item), REML=TRUE)
M8 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**item), REML=TRUE)
M9 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**participant) + (**1|**item), REML=TRUE)
M10 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**participant) + (**expectancy|**item), REML=TRUE)
M11 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**participant) + (**congruence|**item), REML=TRUE)
M12 <- lmer([D.V.] ~ [full fixed extructure] + (**1|**participant) + (**expectancy*congruence|**item), REML=TRUE)
M13 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**participant) + (**1|**item), REML=TRUE)
M14 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**participant) + (1|item), REML=TRUE)
M15 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**participant) + (1|item), REML=TRUE)
M16 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**participant) + (**expectancy|**item), REML=TRUE)
M17 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**participant) + (**congruence|**item), REML=TRUE)
M18 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy|**participant) + (**expectancy*congruence|**item), REML=TRUE)
M19 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**participant) + (**expectancy|**item), REML=TRUE)
M20 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**participant) + (**expectancy|**item), REML=TRUE)
M21 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**participant) + (**congruence|**item), REML=TRUE)
M22 <- lmer([D.V.] ~ [full fixed extructure] + (**congruence|**participant) + (**expectancy*congruence|**item), REML=TRUE)
M23 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**participant) + (**congruence|**item), REML=TRUE)
M24 <- lmer([D.V.] ~ [full fixed extructure] + (**expectancy*congruence|**participant) + (**expectancy*congruence|**item), REML=TRUE)

anova(M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13, M14, M15, M16, M17, M18, M19, M20, M21 , M22, M23, M24)

APPENDIX E. Summary of linear mixed models (Study 2)

Model 1. Linear mixed model on *go-past time* with significant fixed effect of expectation in the target concepts of the text region.

Model 1				
	AIC 9876.50	*BIC* 9899.39	*LogLik* -4933.25	*Deviance* 9866.50
Random effects				
Variable		Variance	SD	
Participant		8007	89.48	
Item		3870	62.21	
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	274.46	22.24	12.34	***0.001
Expectation (0.60)	38.29	16.43	2.33	*0.020

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013)

Model 2. Linear mixed model on *regressions in* with significant fixed effect of expectation in the target concepts of the text region.

Model 2				
AIC	*BIC*	*LogLik*	*Deviance*	
507.34	540.00	-246.67	493.34	
Random effects				
Variable	Variance	SD	Correlation	
Participant	0.008	0.09		
Item	0.002	0.05		
Expectation	0.005	0.07	1.00	
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	0.108	0.023	4.63	***0.001
Expectation (0.46)	0.054	0.028	2.04	*0.049

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013).

Model 3. Linear mixed model on *total time* with significant fixed effect of expectation in the target concepts of the text region.

Model 3				
AIC 10346.44	*BIC* 10379.02		*LogLik* -5166.22	*Deviance* 10332.44
Random effects				
Variable	Variance		SD	Correlation
Participant	4352		65.97	
Item	1295		35.98	
Expectation	2532		50.32	1.00
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	267.99	15.62	17.15	***0.001
Expectation (0.63)	41.25	16.33	2.52	*0.016

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013).

Model 4. Linear mixed model on *total time* with significant fixed effects of congruence and expectation x congruence interaction in the target words of the critical sentence.

Model 4

AIC	*BIC*	*LogLik*	*Deviance*
16420.60	16475.79	-8199.30	16398.60

Random effects

Variable	Variance	SD	Correlation
Participant	8651	93.01	
Congruence	5383	73.37	0.78
Item	50907	225.63	
Congruence	1815	42.60	1.00

Fixed effects

Variable (*)		*β*	*SE*	*t*	*p*
Intercept		475.90	48.60	9.79	***0.001
Congruence	(0.25)	123.94	32.90	3.77	***0.001
Expectation:Congruence	(0.62)				
- unexpected:congruent		81.47	29.78	2.73	**0.006
- unexpected:incongruent		-58.84	29.81	-1.97	*0.049

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013).

Model 5. Linear mixed model on *regressions out* with significant fixed effect of verbal working memory in the target concepts of the text region.

Model 5				
AIC 513.71	*BIC* 536.59	*LogLik* -251.86	*Deviance* 503.71	
Random effects				
Variable	Variance	SD		
Participant	0.0075	0.087		
Item	0.0071	0.084		
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	0.152	0.025	6.05	***0.001
Verbal working memory (0.51) - higher verbal span	-0.003	0.002	-2.05	*0.047

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013)

Model 6. Linear mixed model on *go-past time* with significant fixed effect of expectation x verbal working memory interaction in the target words of the critical sentence.

Model 6				
	AIC	*BIC*	*LogLik*	*Deviance*
	15683.33	15722.55	-7833.66	15667.33
Random effects				
Variable	Variance	SD	Correlation	
Participant	6235	78.96		
Item	58405	241.67		
Expectation	38993	197.47	1.00	
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	445.20	51.23	8.69	***0.001
Expectation:Verbal WM (0.57)				
- expected:verbal working memory	0.10	2.72	0.04	0.971
- unexpected:verbal working memory	-7.50	2.73	-2.75	**0.007

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013)

Model 7. Linear mixed model on *regressions in* with significant fixed effect of expectation x verbal working memory interaction in the target words of the critical sentence.

Model 7				
AIC 1392.91	*BIC* 1433.09	*LogLik* -688.46	*Deviance* 1376.91	
Random effects				
Variable	Variance	SD	Correlation	
Participant	0.01	0.11		
Item	0.02	0.15		
Congruence	0.01	0.08	0.46	
Fixed effects				
Variable (*)	*β*	*SE*	*t*	*p*
Intercept	0.342	0.04	9.16	***0.001
Expectation:Verbal WM (0.76)				
- expected:verbal working memory	-0.007	0.002	-3.11	**0.003
- unexpected:verbal working memory	-0.002	0.002	-0.58	0.560

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013).

Model 8. Linear mixed-model on *accuracy* with significant fixed effect of expectation in the target words of the critical sentence.

Model 8					
AIC	*BIC*	*LogLik*	*Deviance*		
1101.08	1182.46	-534.54	1069.07		
Random effects					
Variable	Variance	SD	Correlation		
Participant	0.01	0.02			
Expectation	0.01	0.11	-0.10		
Item	0.01	0.11			
Expectation	0.07	0.27	-0.38		
Congruence	0.11	0.34	-0.72	0.23	
Expectation:Congruence	0.10	0.32	0.55	-0.44	-0.81
Fixed effects					
Variable (*)	*β*	*SE*	*t*	*p*	
Intercept	0.87	0.02	40.38	***0.001	
Expectation (0.89)	-0.20	0.05	-3.95	***0.001	

(*) Explained deviance ('pamer.fnc' function; Tremblay & Ransijn, 2013).

APPENDIX F. Situation model task used with ERPs (Study 3)

Practice

a) **The scientific** *microscope/binoculars*
The scientist was investigating new bacteria that had been discovered.
He mixed different chemicals in a test tube and emptied the solution into the petri dish.
After a few days, he examined the results.
- *The scientist focused his instrument to see the new organisms more clearly.* [No Update]
He realized that he could not see any results using his **binoculars**.

➢ The scientist was investigating a new gene. [No]

b) **The report** *computer/typewriter*
The secretary looked through the doctor's notes.
She had to be sure that the symptoms were properly recorded for future reference.
She sat down at her desk and spread out the notes.
- *She spent the whole afternoon finishing the large number of notes.* [Neutral]
Her colleagues could not believe that she did all the records on a **typewriter**.

➢ The secretary sat down at her desk. [Yes]

c) **The secret** *sunbathing/sunbed*
The summer is now over.
My friend Charles was tanned from head to toe.
I had gone to the beach several times, but I was still pale.
- *He told me how many sessions he had paid for, to get that dark.* [Update]
Next year, like Charles, I will use a **sunbed**.

➢ Charles was tanned. [Yes]

Experimental texts

1. **The walk** *butterfly/bird*[1]
It was a beautiful summer's day and the flowers in the park were in bloom.
Mrs. Flynn was walking past the flowerbed with her little boy Mike.
She spotted something flying up into the sky.
- *Mike was looking at the ground trying to pick up a yellow flower.* [Neutral]
- *It had decorated wings and was gracefully rising from a delicate flower.* [No Update]
- *It had coloured feathers and was loudly singing a beautiful melody.* [Update]
Mrs. Flynn pointed to the sky to show Mike the **bird**.

➢ It was winter time. [No]

[1] The first three sentences primed a wrong concept ('*butterfly*'). A subsequent sentence could be neutral, no update or update in relation to that concept. Then, the final sentence brought the disambiguating word ('*bird*'; in bold) that was always inconsistent with the prior wrong idea and consistent with the update sentence. ERPs were measured in this word.

2. **Jack and Andy** *snowman/snowballs*
   It had been snowing and all the children were playing in the park.
   Jack and Andy were best friends and worked well as a team.
   They had spent 30 minutes rolling up snow and now they were nearly ready.
   - *Andy's hands were frozen because he had forgotten his gloves.* [Neutral]
   - *Andy had brought an old woollen scarf and hat to put on.* [No Update]
   - *Andy thought that they now had sufficient missiles to win the fight.* [Update]

   In the end, they were really pleased with their **snowballs**.

   ➢ The children were in the park. [Yes]

3. **The cleaner** *bathroom/kitchen*
   The cleaner had so much work to do, she had not yet had time to stop for a rest.
   She wiped down the tiles, cleaned the soap dish, and then rinsed out her cloths.
   Now, as she stood there, she wanted a break.
   - *When she had finished the housework, she would take the rubbish outside.* [Neutral]
   - *The cleaner thought about cleaning the toilet and that grimy shower.* [No Update]
   - *The cleaner opened the refrigerator and took out some cheese and salad.* [Update]

   She left her cleaning things on the floor in the **kitchen**.

   ➢ The cleaner did not have much work to do. [No]

4. **The puppy** *rain/bath*
   Today it was raining again.
   Inside the house it was nice and warm.
   A small brown and white puppy stood dripping by the door.
   - *Meanwhile, the television news could be heard from the living room.* [Neutral]
   - *The puppy scratched and whimpered on the door waiting for his owner.* [No Update]
   - *The bathroom door opened and his owner came in with a thick towel.* [Update]

   The owner had fetched a towel to dry the puppy after the **bath**.

   ➢ It was warm inside the house. [Yes]

5. **The office** *headteacher/dentist*
   The school secretary came into the classroom.
   Gillian was told to report to the office, because she had an appointment with Mr. Brown.
   Gillian followed slowly, wishing she could be back in class.
   - *The long main corridor of the school was empty and quiet.* [Neutral]
   - *Mr. Brown was thinking about how to correct her problems.* [No Update]
   - *Her mother was waiting to take her to have her teeth checked.* [Update]

   Gillian dreaded her appointments with the **dentist**.

   ➢ Gillian was told to report to the playground. [No]

6. **The needle** *operating/dressmaking*
   It had been a long day at the hospital.
   Ann, the surgeon, felt tired, but wanted to get on.
   After adjusting the lamp, she threaded the needle and began.
   - *Ann's reading glasses were pushed down right onto the tip of her nose.* [Neutral]
   - *She thought one last time about the length of the delicate cut.* [No Update]
   - *She thought about the colour of the buttons for the jacket she was making.* [Update]

   Ann was surprised by how good she was at **dressmaking**.

   ➢ Ann adjusted the lamp. [Yes]

7. **The new addition** *baby/kitten*
   Mr. and Mrs. Jones were proud of the new addition to their family.
   Lots of family and friends had been round to have a look.
   Mrs. Jones knew that she would have to be patient with the regular feedings.
   - *Winter was coming, so today they decided to light the fire.* [Neutral]
   - *The tiny new arrival always seemed to be hungry and cried often.* [No Update]
   - *The tiny new pet always seemed to be hungry and meowed often.* [Update]

   Mr. Jones sat on the chair, holding the small **kitten**.

   ➢ Family and friends had been round to visit. [Yes]

8. **The firefighter** *building/plane*
   The firefighter looked out of the window.
   He felt quite anxious, because everyone was watching.
   Soon he would have to jump and he had never done this before.
   - *He looked at his shoes and thought about how good they were for jumping.* [Neutral]
   - *He took a deep breath to calm himself and signalled that he was ready*. [No Update]
   - *He checked his parachute and signalled to the pilot that he was ready.* [Update]

   The others watched him jump from the **plane**.

   ➢ The firefighter looked down from the balcony. [No]

9. **The big game** *stadium (football ground)/home*
   Today was the league cup final.
   Tommy's team was in the final and it had been difficult to get tickets.
   The sound of the whistle signalled the beginning of the first half.
   - *The newspapers had been predicting their victory for two weeks.* [Neutral]
   - *Tommy and his father both leaned forward excitedly.* [No Update]
   - *Tommy* and his father *leaned forwards on the sofa, excitedly.* [Update]

   Tommy and his father were watching the match together at **home**.

   ➢ Tommy's team was in the final. [Yes]

10. **The park** *slide/swing*
    Jenny loved to play at the park near her home.
    Today she had decided to spend some time on the playground equipment.
    What fun it was to climb up to the top and then come back down to the ground.
    - *She liked having Mum there, sitting on the bench nearby, waiting for her.* [Neutral]
    - *She liked having Mum there to greet her each time she came down.* [No Update]
    - *She was going back and forth through the air being pushed by her mom.* [Update]

    Then Jenny's mother said that it was time to get down from the **swing**.

    ➢ Jenny loved to play at park. [Yes]

11. **The house** *buying/burglary*
    The man saw the "For Sale" sign outside the large house in a wealthy neighbourhood.
    He had been looking for a place like this for quite a while.
    He made an appointment with the estate agent to view the house.
    - *The man arrived early and waited for the estate agent in front of the house.* [Neutral]
    - *The man told the estate agent about his desire to move into the area and asked for the price.* [No Update]
    - *The man was a criminal thinking about all the valuable things in the house.* [Update]

    Once in the house, the man started to plan his **burglary**.

    ➢ The man saw a "For Sale" sign. [Yes]

12. **The lion** *gun/camera*
    The famous hunter was on another safari in the jungles of Africa.
    Even though he had hunted for years, this time it felt very different.
    Today, the hunter found a lion's trail and followed it until he got close to the lion.
    - *He adjusted his cap to see properly and looked straight at the animal.* [Neutral]
    - *He focused on the lion, steadied his hand, and took the shot.* [No Update]
    - *He focused on the lion, looking for a nice photo, and took the shot.* [Update]

    The lion startled when he heard the sound of the **camera**.
    - ➢ The safari was in the jungles of Africa. [Yes]

13. **The tracks** *deer/train*
    Annie and her father lived out in the Midwest of America, near a crossing.
    There had been a snowfall over night.
    At the window, her father asked Annie if she could see the tracks.
    - *The window was misted up, so Annie wiped it with her hand*. [Neutral]
    - *There was an animal with antlers walking slowly in the snow.* [No Update]
    - *There was a loud whistle and smoke rose into the sky.* [Update]

    In the snow, Annie could see the tracks of the **train**.
    - ➢ Annie and her father lived in the Middle East. [No]

14. **The stable lad** *horse/bike*
    Harry worked as a stable lad and this was his first race.
    He was a good rider, but this was going to be a difficult race.
    There were lots of excellent riders from all over the county.
    - *Before the start, he looked up at the sky and crossed himself.* [Neutral]
    - *He was wearing his favourite jeans and his hat for good luck.* [No Update]
    - *He checked the height of the handlebar, pedals and both wheels.* [Update]

    The race began and his family cheered as he took the lead on his **bike**.
    - ➢ There were lots of excellent riders. [Yes]

15. **The vampire** *garlic/onion*
    Christine and her friends went to see a horror movie at the cinema.
    It was about some vampires and the villagers who tried to stop them.
    The climax of the movie was when a brave young girl tried to kill the vampire.
    - *The audience was gripped by the unfolding horror.* [Neutral]
    - *The vampire would die if he ate the white vegetable.* [No Update]
    - *The vampire would die if he ate the round vegetable that it makes cry.* [Update]

    In the end, Christine was glad to see the vampire die after eating the **onion**.
    - ➢ The reviews of the film were bad. [No]

16. **The destination** *hospital/library*
    Erin was not feeling well so she took a bus into the city.
    She was hoping that she would soon find out what was wrong.
    The bus stopped right outside her destination.
    - *The people waiting at the bus stop started to board the bus.* [Neutral]
    - *She thought about her last trip here, when she had a broken leg.* [No Update]
    - *She thought about the last time that she came here to borrow a book.* [Update]

    She walked through the door and entered the **library**.
    - ➢ Erin took a taxi into the city. [No]

17. **The mystery** character/murderer
The man lived alone in the huge mansion.
This evening, he was sitting on the sofa reading his detective novel.
The curtains were closed and everything was silent.
- *The cuckoo clock sounded at eight p.m., ending with a soft bell sound.* [Neutral]
- *Turning the page, he knew that someone had entered the house with a knife.* [No Update]
- *He heard someone enter the room and saw them standing there with a knife.* [Update]

The man thought that the knife would be used by the **murderer**.

➢ The curtains were open. [No]

18. **Cooking** *stove/campfire*
Frank and his father were discussing what to have for dinner.
The decision would have been easier if mum had been there.
Finally, they decided to cook pasta and meatballs.
- *Frank wanted to make two meatballs for him and three for his father.* [Neutral]
- *Frank filled the pan with water and added a pinch of salt.* [No Update]
- *Frank arranged some twigs and his father got out the matches.* [Update]

Frank's father told his son to keep an eye on the **campfire.**

➢ Frank and his father decided to cook steak. [No]

19. **The fish** *shark/squid*
It was a hot summer's afternoon.
Peter and his friends were at the beach.
Peter ignored the warning flag and went for a swim.
- *Peter made out a small shape of a sailboat on the sea near the horizon.* [Neutral]
- *Suddenly, Peter recognized the shape that was swimming towards him and felt the fear in his bones.* [No Update]
- *Suddenly, Peter saw the tentacles of the animal moving towards him and felt curious.* [Update]

It was the first time that Peter had seen a **squid**.

➢ There was a warning flag. [Yes]

20. **The workman** *hammer/tyre*
The workman had a busy day ahead.
He had his long ladder, his power saw, and a stack of timber ready for him.
Everything was going well, until he struck that nail.
- *He had forgotten the phone, so he could not call anyone at that moment.* [Neutral]
- *He was always very careful and wore gloves to protect his hands.* [No Update]
- *He was driving along, when he spotted the big nail in the road ahead.* [Update]

The workman knew that the nail had damaged the **tyre**.

➢ The workman had a long ladder and a power saw. [Yes]

21. **The breakfast** *bacon (and eggs)/cereal*
After his shower, Billy went downstairs to the kitchen.
A welcoming smell greeted him.
His girlfriend, Susie, was standing by the cooker preparing breakfast.
- *Susie said good morning and smiled across at him.* [Neutral]
- *Susie had already laid the table and made the coffee.* [No Update]
- *On the table, Susie had put out bowls and spoons.* [Update]

Billy's stomach rumbled as he waited for his **cereal**.

➢ The kitchen was upstairs. [No]

22. **Baking** *cookies/decorations*
   Jim and Jane were in the kitchen mixing the flour and butter with enthusiasm.
   Once the dough was ready, they rolled it flat.
   They cut the dough into different shapes and baked them in the oven.
   - *Their father snorted when he saw the mess they had made in the kitchen.* [Neutral]
   - *Then the children waited eagerly while the small pieces cooled on a plate.* [No Update]
   - *Then the children painted the small pieces before hanging them on the Christmas tree.* [Update]

   The children's mother was proud with the shapes of the **decorations**.

   ➢ Jim and Jane rolled the dough flat. [Yes]

23. **The memory** *armchair (rocking chair)/hammock*
   Bryan had returned to see his childhood home, back in northern Texas.
   It had a veranda, which looked onto a large garden.
   He remembered how his mother would always go there to read, after lunch.
   - *The window panes were broken and the house was now empty inside.* [Neutral]
   - *He could remember her humming gently, as she read in the shade.* [No Update]
   - *He remembered her lying there, swinging between the two stout trees in the shade.* [Update]

   Bryan felt nostalgic and wished he could be in his mother's **hammock**.

   ➢ The house was in northern Moscow. [No]

24. **The lunch** *girlfriend/neighbour*
   This Sunday, Joseph invited his girlfriend round to his new flat for lunch.
   He checked the roast in the oven, set out the table, and waited for her to arrive.
   At half past twelve the doorbell rang and Joseph went to the door.
   - *At the same time, the oven timer indicated that the roast was ready.* [Neutral]
   - *Claire was standing there with a cake for dessert.* [No Update]
   - *Claire, from downstairs, had brought round his post.* [Update]

   Joseph opened the door and said thanks to his **neighbour**.

   ➢ The doorbell rang at two o'clock. [No]

25. **The wedding** *straight/gay*
   It was the day of Robert's wedding.
   He dressed himself carefully, imagining his partner in the same situation.
   His best man drove him to the registry office in good time.
   - *Many of his friends and relatives were there waiting for his arrival.* [Neutral]
   - *Looking around, Robert spotted the blonde hair of his future spouse.* [No Update]
   - *Looking around, Robert spotted the blonde beard of his future husband.* [Update]

   Today, Robert felt especially proud to be **gay**.

   ➢ Robert dressed himself quickly. [No]

26. **The thirsty** *water/lemonade*
   The runner had now been running for over an hour.
   During that time, she had not had anything to drink.
   She was incredibly thirsty and took a drink from the table as she went past.
   - *After drinking she tossed the bottle into a bin and continued running.* [Neutral]
   - *She drank the clear liquid in two gulps and felt much better.* [No Update]
   - *She drank the sweet, clear, sparkling liquid and felt much better.* [Update]

   The runner would be able to finish the race now she had drunk some **lemonade**.

   ➢ The runner took the drink from the bar. [No]

27. **The baby** *pregnancy/adoption*
The couple was very excited.
Soon they would be parents.
They both remembered the time when they knew they would have a baby daughter.
- *They had painted the room pink and bought lots of toys.* [Neutral]
- *Nine months had felt long enough and now they wanted to see their baby.* [No Update]
- *It had taken nine months to get the paperwork completed for the Chinese baby.* [Update]

In the end, they realized that nine months was not that long to wait for an **adoption**.

➢ The baby was a girl. [Yes]

28. **The farm** *cat/dog*
On the farm, the horses were in the stable because it was raining.
Down in the straw, a mouse was looking for something to eat.
A bigger animal, hidden in the corner, was watching.
- *The mouse found a piece of fruit and began to eat.* [Neutral]
- *It jumped out and scared the mouse.* [No Update]
- *It barked loudly and scared the mouse.* [Update]

Farmer Campbell walked into the stable and saw the mouse in the mouth of his **dog**.

➢ It was a sunny day. [No]

29. **The darkness** *candle/lamp (electrical)*
It was a warm summer's night and Bruce was in his room playing his guitar.
The room was softly lit with a warm smell of incense.
The window was open and there was a gentle wind outside.
- *Bruce was playing his favourite song when it went dark.* [Neutral]
- *Suddenly, the light flickered and blew out leaving Bruce in darkness.* [No Update]
- *Suddenly, the bulb flickered and Bruce was left in darkness.* [Update]

Bruce put down his guitar and walked over to the **lamp**.

➢ The window was closed. [No]

30. **The couple** *wife/lover*
The couple who walked into the hotel lobby could not take their e[Yes] off each other.
I wondered if they were newlyweds.
The man put his arm around the woman and they walked to the elevator.
- *When the elevator arrived, the couple entered it and I did the same.* [Neutral]
- *I saw the man bend down and kiss the woman just behind her ear.* [No Update]
- *The man slipped off his wedding ring and put it in his pocket.* [Update]

Once in the elevator I realized that the woman was his **lover**.

➢ The couple could not take their e[Yes] off each other. [Yes]

31. **The gully** *falling (suicide)/paragliding*
Some people thought that David was an unlucky man.
He had lost his job and now his wife had left him.
Today he drove up to the clifftops near his home.
- *After parking, he got out of the car and stood thinking for a while.* [Neutral]
- *After a while standing there, he ran to the edge and jumped.* [No Update]
- *He checked his parachute and jumped off the edge.* [Update]

Once in the air, David fell quickly while **paragliding**.

➢ David had driven up to the clifftops. [Yes]

32. **The artist** *painting/cake*
    The artist admired his creation as he brushed his dirty hands on his apron.
    It was almost perfect.
    Now he just had to add the finishing touches.
    - *The doorbell rang just as the artist had finished.* [Neutral]
    - *He mixed some blue to make his distinctive mark.* [No Update]
    - *He mixed some more icing to add to the sides.* [Update]

    His wife was surprised when he gave her the **cake**.

    ➢ The artist brushed his hands on his apron. [Yes]

33. **The long day** *swim/bath*
    Jodi stood on the hotel balcony.
    There were only a few people in the pool, below.
    Jodi quickly changed out of her dress and was soon ready to get into the water.
    - *It was her second day at the hotel, and she still had three more days left.* [Neutral]
    - *Before getting in, she dipped in her foot to check the temperature.* [No Update]
    - *When she had run the water, she checked the temperature with her hand.* [Update]

    All day long, Jodi had been looking forward to that **bath**.

    ➢ There were a lot of people in the pool. [No]

34. **The logs** *axe/saw*
    Dave looked at the fallen branch.
    It would make excellent logs for the fire.
    He went to the shed to fetch his favourite tool.
    - *The shed was cluttered but he quickly found the tool.* [Neutral]
    - *The handle was smooth from years of use.* [No Update]
    - *The serrated blade looked a little rusty.* [Update]

    Dave put on his gloves and picked up his **saw**.

    ➢ Dave had gone to the garage. [No]

35. **The juice** *orange/apples*
    My daughters drink lots of fruit juice.
    This year, I bought a juicer so I can make it fresh each day.
    Pam, my youngest, is fussy and prefers one type of juice.
    - *In fact, she will only drink her juice through a straw.* [Neutral]
    - *Her favourite fruit is round and contains plenty of vitamin C.* [No Update]
    - *Her favourite fruit has red peel and comes from our own orchard.* [Update]

    Now, every morning to make the juice I have to peel three **apples**.

    ➢ Pam is the oldest sister. [No]

36. **The funeral** *burial/cremation*
    Today was the funeral of the much loved aunt.
    The priest had said the prayer.
    Now it was time for the family to say their final goodbye.
    - *The daughter expressed sadly her love to her.* [Neutral]
    - *The daughter placed a single rose on the coffin.* [No Update]
    - *The family planned to scatter the ashes in the rose garden.* [Update]

    It was the first time that the children had been to a **cremation**.

    ➢ The prayer was said by a relative. [No]

37. **The sleeplessness** *fever/nightmare*
The little girl had not been well for several days.
However, tonight she was back in her own bedroom, sleeping alone.
In the middle of the night, she woke up in a sweat and felt delirious.
- *Her mother woke up and came into her room.* [Neutral]
- *Her mother came in and told her not to worry.* [No Update]
- *Her mother came in and said it was just a bad dream.* [Update]

The mother hoped that soon there would be an end to the **nightmares**.

➢ The little girl was sleeping alone. [Yes]

38. **The musician** *guitar/violin*
Dan was a gypsy who had played flamenco since childhood.
Now he is a popular musician who plays all over the world.
Today, he is giving a recital of his favourite works.
- *The concert takes place at the prestigious national concert hall.* [Neutral]
- *His instrument is made of maple wood, with a beautiful curved body.* [No Update]
- *His instrument is made of maple wood with a matching bow.* [Update]

The public was delighted to hear Dan playing the **violin**.

➢ In the recital, Dan played his favourite works. [Yes]

39. **The event** *fight/play*
The tension between the two men was high.
One of them took advantage and smacked the other straight on the jaw.
The people watching could not believe what they were seeing.
- *One of the men was older with slightly greying hair.* [Neutral]
- *The men became more and more aggressive.* [No Update]
- *The actors were very convincing in their roles.* [Update]

That moment was the most violent of the **play**.

➢ One man smacked the other on the leg. [No]

40. **The cinema** *popcorn/icecream*
Grace was very excited when she got to the cinema.
It was the premiere of the film based on the book she had just read.
She bought a soft drink and a large tub of her favourite snack, which she only ever bought at the cinema.
- *As soon as she sat down, Grace relaxed and focused on the screen.* [Neutral]
- *As soon as she sat down, Grace opened the tub and began to eat.* [No Update]
- *As soon as she sat down, Grace undid the wrapper before it melted.* [Update]

In five minutes, she had finished eating her **icecream**.

➢ The film was based on a book. [Yes]

41. **The removal** *mirror/photograph*
Mr. and Mrs. Harrison were in their new apartment.
They were unpacking their belongings and deciding where to put everything.
Mrs. Harrison was looking for something to hang on the bathroom wall.
- *She found some wire and a hook and hung it on the wall.* [Neutral]
- *She saw her reflection in the glass as she picked up the frame.* [No Update]
- *She looked at the wedding scene as she picked up the frame.* [Update]

Mr. Harrison said it was a beautiful **photograph**.

➢ Mr. and Mrs. Harrison had a new apartment. [Yes]

42. **The excursion** *zoo/aquarium*
Emma is a five years old girl who loves animals.
Today she is especially happy.
Her parents are taking her to her favourite place.
- *It took almost an hour to get there, but at last they arrived.* [Neutral]
- *There she can see creatures from all over the world.* [No Update]
- *There she can see many fish of various colours and shapes.* [Update]

She looked at the huge sign over the entrance, which read **aquarium**.

➢ Emma's grandparents were taking her out. [No]

43. **The field** *bull/cow*
Ed was lying on his back in the field on a warm summer's day.
He heard a noise and looked up and saw the huge black animal.
Ed felt terrified looking into its big eyes whilst it towered over him.
- *Ed closed his e[Yes] and stayed still, hoping the animal to go away.* [Neutral]
- *The big animal had big horns and ring through its nose.* [No Update]
- *The big animal with udders moved its leg, and mooed loudly.* [Update]

The farmer shouted and scared the **cow**.

➢ The animal was brown. [No]

44. **The hike** *head/bottle*
Sam was proud to be a member of his Boy Scout troop.
Today, the troop was on a hike up a mountain.
It was a sunny day and as they got near the summit the wind picked up.
- *Sam grabbed his bag tightly and hurried on with determination.* [Neutral]
- *Sam noticed the wind and made sure that he pulled his cap on tight.* [No Update]
- *Sam had a drink and made sure that he fastened the cap tight.* [Update]

The scoutmaster understood why Sam secured the cap on his **bottle**.

➢ The troop was going to the beach. [No]

45. **The immigrants** *headscarf/hairband*
The Muslim family was having problems integrating into the new society.
For example, little Eylem's first day of school was very stressful for her.
The other children were mean and pointed at her at her head.
- *During break time, Eylem preferred sit alone away from the other children.* [Neutral]
- *Eylem had got dressed in her usual clothes for school that day.* [No Update]
- *Eylem had tied back her hair to keep it off her face.* [Update]

The teacher punished the children who mocked at Eylem's **hairband**.

➢ It was the first day of school for Eylem. [Yes]

46. **The bus** *inspector/passenger*
It was a cold January morning.
The bus to the University arrived; I got on and found a seat.
A serious man wearing a peaked cap and jacket got on as well.
- *The bus doors closed and the driver pulled back out into the road.* [Neutral]
- *The man checked the date and the wording on each ticket very carefully.* [No Update]
- *The old man checked his own ticket closely, trying to read the date.* [Update]

I noticed the thick glasses worn by this **passenger**.

➢ It was a July morning. [No]

47. **The rain** *umbrella/anorak*
Today, it was raining heavily.
Liza had an important meeting and did not want her hair to get ruined.
Before leaving the house, she grabbed something to keep herself dry.
- *She also picked up her computer bag, which she had packed the night before.* [Neutral]
- *It was still there in the porch, where she had left it to dry last night.* [No Update]
- *It was hanging by its hood in the porch, where she had left it to dry.* [Update]

On her walk to work, Liza was glad that she had an **anorak**.

➢ Liza did not want her shoes to get ruined. [No]

48. **The horoscope** *newspaper/computer*
On Saturday mornings, Sara always reads her weekly horoscope.
She looks forward to this all week.
This Saturday, she made herself some coffee and sat in her favourite chair.
- *She had all morning to read quietly.* [Neutral]
- *She went straight to the right page.* [No Update]
- *She clicked straight on the right link.* [Update]

She carefully read her horoscope on the **computer**.

➢ Sara reads the weekly horoscope on Sundays. [No]

49. **The desert** *camel/snake*
Tuaregs are Berber nomadic people, inhabitants of Sahara's desert.
The Tuareg Isham had been travelling with his animal through the dunes on a long journey.
He stopped at an oasis so that they could both drink.
- *They were both thirsty and Isham needed to rest for a while.* [Neutral]
- *The brown animal next to him was waving its tail slowly.* [No Update]
- *The animal was slithering next to him, its forked tongue darting.* [Update]

After hours, Isham found an oasis where he could give some water to his **snake**.

➢ Isham had been moving through some dunes. [Yes]

50. **The energy-giving drink** *coffee/coke*
By mid-morning, Eve always felt a little tired.
She would go down to the drinks machine to get her daily pick-me-up.
She put the coins in the slot and entered the code.
- *In a few minutes she was back at her desk with the drink.* [Neutral]
- *The drink always gave her the mid-morning boost she needed.* [No Update]
- *The fizzy cold drink tasted sweet and gave her a boost.* [Update]

Eve always felt perkier after her **coke**.

➢ Eve had to enter a code for her drink. [Yes]

51. **The jungle** *lion/elephant*
Many different animals were gathering around the waterhole.
This was a popular spot at this time of day.
The antelope looked nervous when the newcomer arrived.
- *It was very hot and the water cooled them down nicely.* [Neutral]
- *The animal walked slowly waving his tail.* [No Update]
- *The animal walked slowly waving his trunk.* [Update]

The rest of animals moved to make space for the **elephant**.

➢ Many animals were around the waterhole. [Yes]

52. **The skin** *chickenpox/acne*
Alex was a rather sickly teenager.
Today he did not feel well and told his mum that he did not want to go to school.
He decided to stay in bed.
- *His mother told him that he could stay at home.* [Neutral]
- *His mother noticed some small red spots on his face.* [No Update]
- *His mother noticed some pimples on his chin.* [Update]

His mother went to the pharmacy and bought something for his **acne**.

➢ Alex wanted to go to school. [No]

53. **Mr. and Mrs. Potter** *people/monkeys*
Mr. and Mrs. Potter had lived together for a few years now.
They used to exercise together, every morning.
Mr. Potter was sick so he could not exercise at the moment.
- *In the end, Mrs. Potter did not exercise that morning either.* [Neutral]
- *Mrs. Potter liked to stay with him for company.* [No Update]
- *Mrs. Potter stayed with him in the cage, grooming his fur.* [Update]

Some families often came to visit these lovely **monkeys**.

➢ Mr. and Mrs. Potter used to exercise together. [Yes]

54. **The morning** *bell (alarm clock)/cockerel*
Mr. Martin lives several miles out of town.
Every morning, he wakes up early: it is a long drive to the office.
It was six, when the noise woke him up this morning.
- *After stretching he jumped out of the bed.* [Neutral]
- *The loud melody was repeated several times.* [No Update]
- *The loud crowing was repeated several times.* [Update]

Mr. Martin thought it was great to be woken up by the **cockerel**.

➢ It was six when the noise woke Martin up. [Yes]

55. **The time** *watch/hourglass*
Four friends were playing a board game.
Now it was Bob's turn and he had one minute to draw the word on the card.
Debbie checked the time and then told Bob to start.
- *Debbie kept laughing as she looked at Bob's drawing.* [Neutral]
- *Debbie watched the minute pass, second by second.* [No Update]
- *Debbie watched the sand trickle through, second by second.* [Update]

Bob was not sure he would finish his drawing in time as he glanced at the **hourglass**.

➢ Bob had to draw a picture of the word on the card. [Yes]

56. **The dessert** *strawberry/blackberries*
After lunch, Mrs. Wells liked to have fruit for dessert.
She grew her favourite fruit in her garden.
Today, she decided to be decadent and have a bowlful with cream.
- *She went back in the kitchen, got out a bowl and prepared her dessert.* [Neutral]
- *She removed the leaves carefully, so as not to damage the berries.* [No Update]
- *She removed the leaves carefully, so as not to get purple stains on her fingers.* [Update]

Mrs. Wells got a spoon and started to eat the **blackberries**.

➢ Mrs. Wells used to eat fruit for breakfast. [No]

57. **The fruit** *banana/lemon*
Jessica was the most popular monkey in the zoo.
She got lots of attention from the zookeeper, especially treats.
That afternoon Jessica received a piece of fruit as treat.
- *Jessica realized that she was in the spotlight.* [Neutral]
- *Jessica savoured the taste of the yellow fruit.* [No Update]
- *Jessica sucked on the sour yellow fruit.* [Update]

It was the first time that Jessica had tasted a **lemon**.

➢ The zookeeper neglected Jessica's diet. [No]

58. **The car** *repair/petrol*
Oliver was driving up to Scotland when his car made an odd sound and then stopped.
He called the breakdown service, which sent a breakdown van to assist.
The van brought the car and its driver to the nearest garage.
- *In less than an hour he was ready to continue his journey to Scotland.* [Neutral]
- *At the garage, a man quickly solved the problem with the car.* [No Update]
- *At the garage, they filled up the tank so the car was ready to go again.* [Update]

Oliver was pleased and paid for the **petrol**.

➢ The car and its driver were brought to the garage by a tractor. [No]

59. **The sky** *kite/balloon*
Little Ben loved being pushed by his father in his pram.
He would lie back and watch the birds in the sky above.
Today it was windy and he saw something different in the sky.
- *Ben sat up in his pram and stared up at the sky, smiling.* [Neutral]
- *It was shaped like a bird, but a boy carefully guided it with some strings.* [No Update]
- *It was red and round, and a boy was holding onto its string tightly.* [Update]

Ben's father pointed out to show him the **balloon**.

➢ Little Ben liked to lie back in his pram. [Yes]

60. **Shopping** *greengrocer/butcher*
Mr. Smith ran his own shop on the high street, which sold organic produce.
Although he ran a box scheme, many people still came in to the shop.
The first customer today was the mayor's wife.
- *She trusted Mr. Smith so she let him to advice her.* [Neutral]
- *She checked her list to see what items she needed.* [No Update]
- *She checked her list and bought a chicken and some sausages.* [Update]

The woman paid the bill and thanked the **butcher**.

➢ The first customer was a man. [No]

61. **The elevator** *up/down*
I was visiting a dear old family friend who lives in an exclusive apartment block in Manhattan.
I did not have to wait long for the elevator to arrive.
When the door opened, I entered and pressed the floor number.
- *In under a minute until the elevator doors opened and I could come out.* [Neutral]
- *The elevator doors opened smoothly and I saw Mr. Clark standing there.* [No Update]
- *The elevator doors opened and I saw the doorman waiting at the entrance.* [Update]

In the elevator, I checked my phone for messages as it was going **down**.

➢ My family friend lives in an exclusive apartment block. [Yes]

62. **The mount** *horse/donkey*
The rider got out the saddle and reins and secured them.
Everything was ready for his ride through the mountain vineyards.
He got up on the saddle and started to ride.
- *The first stop was after four kilometers, at the top of the mountain.* [Neutral]
- *The animal had a beautiful coat and a long tail.* [No Update]
- *The animal had long pricked up ears, and often brayed loudly.* [Update]

The rider had an excellent view of the mountains on top of his **donkey**.

➢ The rider secured the reins. [Yes]

63. **Mexican beer** *bottle/can*
It was Bob's birthday party and he was having a barbecue.
He had bought lots of Mexican beer, which he was keeping cold in the fridge.
Dave, his mate, handed him a fresh beer.
- *Bob gave Dave a knowing wink, showing his appreciation.* [Neutral]
- *Bob found it hard to open because his hands were greasy from cooking.* [No Update]
- *Bob opened the beer and threw the ring-pull in the bin.* [Update]

Finally, Bob opened the beer and drank from the **can**.

➢ The beer was keeping cold in the garden. [No]

64. **The agreement** *flat/car*
The landlord discussed terms and conditions with the new tenant.
He often rented to new people and liked to show them around himself.
The new tenant was anxious to come to an agreement.
- *The landlord then fixed the conditions and the total price to pay.* [Neutral]
- *The landlord held the door open for the tenant to look around one last time.* [No Update]
- *The landlord showed him a small backroom where he could store spare tyres and oil.* [Update]

The tenant accepted the terms and signed the contract to rent the **car**.

➢ The tenant was anxious to come to an agreement. [Yes]

65. **The insect** *bee/dragonfly*
Daphne was in the park having a picnic with friends.
For the picnic, Daphne had brought scones and jam.
An insect flew towards them.
- *A friend ran away from the food with a scared look on her face.* [Neutral]
- *It had yellow and brown stripes and flew straight past the group.* [No Update]
- *It had a bright blue body, lacey wings, and headed to the pond.* [Update]

Daphne and her friends watched the **dragonfly**.

➢ Daphne was having a picnic with friends. [Yes]

66. **The poverty** *food/games*
The documentary was about how famine in the 'Third World' was getting worse.
In southern Africa especially, the incidence of malnutrition has increased hugely over the last few years.
A young boy almost naked was crying desperate in the middle of nowhere.
- *It was a village in the southwest, near Cape Town.* [Neutral]
- *The poor child did not have many things in his house.* [No Update]
- *The poor child did not have many things to play with in his house.* [Update]

The documentary maker told that the boy suffered the shortage of **games**.

- ➢ The documentary was showing the situation in southern China. [No]

67. **Mother's knowledge** *suffering/lying*
This morning Sarah's son woke up complaining of a bad headache.
His mother knew what to do.
She made a phone call and helped her son to get into the car.
- *During the journey, Sarah listened to the local news on the radio.* [Neutral]
- *During the journey, Sarah's son had his hand on his forehead.* [No Update]
- *During the journey, Sarah's son was pretending to be ill.* [Update]

After parking the car, Sarah realized that her son was **lying**.

- ➢ Sarah did not know what to do with her son's headache. [No]

68. **The story** *broom/cart*
The father was reading a fairy tale to Susie and Charlie.
On each page, the children looked at the pictures and asked questions about the story.
The main character was a witch who got to escape through the mountains.
- *The witch wore black clothes, in the middle of night, and had an evil laugh.* [Neutral]
- *The witch walked away, in her pointed hat, giving a shrill laugh.* [No Update]
- *The witch walked away guiding a horse that pulled the wooden wheels.* [Update]

Charlie asked why the witch got away in a **cart**.

- ➢ Susie and Charlie were listening their mother reading a fairy tale. [No]

69. **The game** *chess/poker*
Today it was being played the most important tournament of the city.
The last two players were concentrating hard at each end of the table.
Both of them were looking at the time when they had to make a decision.
- *One of the players asked for a glass of water without removing the gaze from the game.* [Neutral]
- *One of the players was very nervous and carefully observed each move of his opponent.* [No Update]
- *One of the players wore sunglasses trying to conceal any expression that could indicate his cards.* [Update]

After an hour and a half they finished the game of **poker**.

- ➢ It was the most important tournament of the city. [Yes]

70. **The river** *frog/turtle*
In the pond in my village there is a huge variety of plants and animals.
Sometimes the sound of croaking is really loud.
Last Tuesday it was very noisy so I went to investigate.
- *It was very dark so I could not see very well.* [Neutral]
- *There was a green animal sitting on a water lily.* [No Update]
- *There was a small animal with a shell on a water lily.* [Update]

In the end I realized that it was a **turtle**.

- ➢ There was a huge variety of plants and animals in the lake. [No]

71. **The thief** *cash/pizza*
Samuel is a petty thief.
He is currently serving a three month prison sentence.
A month ago, he was caught robbing a shop.
- *The camera footage was the decisive evidence against Samuel.* [Neutral]
- *A camera recorded how Samuel got in and left the shop with a full bag.* [No Update]
- *A camera recorded how Samuel got a whole bag filled with Italian food.* [Update]

The police easily understood how the thief had stolen a lot of **pizza**.

➢ Samuel was serving a one year prison sentence. [No]

72. **The baby** *milk/water*
The baby used to cry very loudly when he was hungry.
His father thought how easy it would be if his wife were there to breastfeed the child.
But the mother was at work and now the father had to feed his little boy.
- *He picked up the desperate baby and carried him down to the kitchen.* [Neutral]
- *He filled the feeding bottle and gave it to his baby to drink.* [No Update]
- *He filled the feeding bottle with fruit drink and gave it to the baby.* [Update]

The father was pleased to see the soothed baby drinking the **juice**.

➢ The mother of the baby had died. [No]

73. **The bride** *tiara/bonnet*
At the dentist's surgery, I took one of the cheap magazines from the table.
One page showed the royal wedding of some remote country.
Everyone was talking about the expensive outfit worn by the bride.
- *The bride stood in front of the palace greeting the people who had come.* [Neutral]
- *The bride stood out because of the shinning accessory on her head.* [No Update]
- *The bride stood out because of the sunhat with a brim on her head.* [Update]

Many women who had attended could not stop looking at her **bonnet**.

➢ The magazine was at the dentist's surgery. [Yes]

74. **The swimmer** *goggles/glasses*
As she did every afternoon, the swimmer went to the pool.
In the changing room, she realised that she did not have anything to help her to see in the water.
She picked up her things and drove home.
- *She was expecting the traffic to be light on the route.* [Neutral]
- *She was expecting to find the blue case by the door.* [No Update]
- *She was expecting to find her spectacles case in the bedroom.* [Update]

Driving back to the pool, she was now happy to have her **glasses**.

➢ The swimmer used to go to the swimming pool in the morning. [No]

75. **The security** *helmet/harness*
The builder knew only too well how risky it was to work on the demolition site.
A few days ago a large stone fell from a wall directly onto his head.
Fortunately, he was always well protected.
- *The builder had some bruises but in the end it was nothing serious.* [Neutral]
- *The builder's safety was guaranteed by the fastening of the strap.* [No Update]
- *The fastening of the strap protected the builder's body from legs to shoulders.* [Update]

It was not the first time that he saved his life with the **harness**.

➢ The builder was working on the demolition site. [Yes]

76. **The idol** *trumpet/piano*
Ethan played an instrument in a Jazz band.
He really admired Louis Armstrong who was his idol.
Ethan tried to imitate his characteristic inflated cheeks movement.
- *Every day, he dreamt of becoming a professional musician.* [Neutral]
- *Every day, he stood in front of the mirror playing his instrument.* [No Update]
- *Every day, he sat close to the instrument playing its keys.* [Update]

Ethan could pass hours playing his **piano**.

➢ The idol of Ethan was Ray Charles. [No]

77. **The Greek museum** *sculpture/picture*
Kathie was visiting the ancient Greek museum in Athens.
She had been studying the proportions of the human body for a long time.
Now she could appreciate these marble works of art.
- *In the third corridor, Kathie recognized one of the works.* [Neutral]
- *In the third corridor, Kathie was very impressed by a figure.* [No Update]
- *In the third corridor, Kathie was very impressed by a two-dimensional work.* [Update]

She remembered when she had to study that particular **picture**.

➢ Kathie was in Athens. [Yes]

78. **Global Warming** *(polar) bear/seal*
Global Warming is bringing about irreparable damage to our ecosystem.
In the North Pole for example, the reduction of icebergs is resulting in the death of many animals.
The other day on TV I saw an animal isolated in the melt water.
- *BBC documentaries have always managed to film the stark reality.* [Neutral]
- *The desperation of the big hairy animal made me sad.* [No Update]
- *The desperation of the grey animal with flippers and whiskers shocked me.* [Update]

I changed the channel when I started feel very sad for that **seal**.

➢ The documentary was about Global Warming. [Yes]

79. **Wild West** *boots/trainers*
Our office party this year had a Wild West theme.
Some of my colleagues were really imaginative and dressed up as a cactus or a horse.
Robert had the simplest outfit and dressed up as a cowboy.
- *He had been working all day and had no time to prepare his costume.* [Neutral]
- *He was wearing a cowboy hat on his head and a pair of shoes with buckles.* [No Update]
- *He was wearing a cowboy hat on his head and a pair of sports shoes.* [Update]

Arriving at the party, Robert felt uncomfortable with his pair of **trainers**.

➢ Robert's costume was the simplest of the party. [Yes]

80. **The tectonic plates** *lava/smoke*
Our teacher explained that the tectonic plates of the Earth are still active.
Especially in volcanic areas, the crash between these plates can cause huge catastrophes.
We also learnt that damage can be caused by the seepage from the centre of the volcano.
- *Many plant species disappear each year for this very reason.* [Neutral]
- *The volcano's eruptions can cause irreparable disasters in the area.* [No Update]
- *The gaseous and dark fumes of a volcano's eruptions can cause disasters.* [Update]

To show it to us, our teacher drew on the board the seepage of **smoke**.

➢ The tectonic plates can produce the leak of volcanic residues. [Yes]

81. **The Scotsman** *kilt/coat*
Most evenings the traditional Scotsman played his bagpipes up on the hill.
As he did so, he thought of his ancestors and their traditions.
That night the wind was blowing fiercely and his legs had goose bumps.
- *The Scotsman was not cold because he was engrossed with the melody.* [Neutral]
- *The Scotsman was wearing a traditional garment with nothing underneath.* [No Update]
- *The Scotsman was wearing an outdoor jacket with little underneath.* [Update]

That night he had to stop playing because the wind strongly blew about his **coat**.

➢ The Scotsman had goose bumps. [Yes]

82. **The wise** *books/photos*
Ernest is the oldest librarian in my city.
Everyone believes that he is the wisest man in the area.
He used to read all the time, and has an impressive knowledge of the world.
- *Ernest has a thousand stories to tell in every situation.* [Neutral]
- *Ernest has a huge collection from which he learnt.* [No Update]
- *Ernest has a huge collection of pictures from which he learnt.* [Update]

Ernest has invited the local schoolchildren to visit his huge collection of **photos**.

➢ Ernest had an impressive knowledge of the world. [Yes]

83. **The wheel** *bicycle/scooter*
The **mountain ride** was difficult from the beginning.
The well-known competitor started to sweat profusely.
He was going at full speed among the sharp rocks.
- *The competitor knew that he was about to reach the finish line.* [Neutral]
- *The competitor was working flat out while he went uphill.* [No Update]
- *The competitor was working flat out while he accelerated uphill.* [Update]

With the rain, the stony ground punctured the wheel of his **scooter**.

➢ There were sharp rocks on the floor. [Yes]

84. **The match** *hoop/goal*
Aggie started to play basketball two weeks ago.
Now she trains with her team every week.
During a recent match she caught the ball and quickly positioned herself.
- *Aggie felt the spectators' tension when she threw the ball.* [Neutral]
- *Aggie carefully directed the ball towards its target.* [No Update]
- *Aggie carefully kicked the ball towards its target.* [Update]

The crowd applauded as the ball entered the **goal**.

➢ Aggie had started to play basketball two months ago. [No]

85. **The food** *chilli/pesto*
The Mexican Carlos was having lunch.
He played in a Mariachi band, so he loved to dress in his traditional costume with its big cap.
Now he was having his typical meal, a tasty burrito.
- *The Mexican Carlos tasted the burrito and smiled and licked his lips.* [Neutral]
- *The Mexican Carlos had put a lot of his favourite sauce on the burrito.* [No Update]
- *The Mexican Carlos had put a lot of basil sauce on the burrito.* [Update]

After he had finished eating he could still taste the **pesto**.

➢ The Mexican liked to wear a big cap. [Yes]

86. **World Heritage** *Coliseum/Vatican*
Europe has many important historic buildings recognized as World Heritage.
My aunt told me that the Roman Empire made a great contribution.
They built many amphitheatres and circuses in different places.
- *She told me about a representative example of World Heritage building.* [Neutral]
- *In Rome, there is a famous example of incredible dimensions.* [No Update]
- *In Rome, there is a group of buildings constituting the Holy See*. [Update]

This World Heritage place is known with the name of **Vatican**.

➢ The Roman Empire built many World Heritage buildings. [Yes]

87. **The show** *ballerina/actress*
There were just a few people in the audience.
The music was already playing when the dancer turned up.
Even the barman stopped his work to watch her wonderful movements.
- *The woman had an innate ability to make everyone speechless.* [Neutral]
- *The woman was standing on tiptoe, raising her hands in a circle.* [No Update]
- *The woman was standing on the stage, playing a femme fatale.* [Update]

At the end, the public gave a standing ovation to the **actress**.

➢ The barman did not see the movements of the dancer. [No]

88. **The dinner** *pasta/couscous*
The supermarket was packed with people.
The young Italian had decided to cook a traditional dinner to impress his new flatmates.
He found the parmesan and now he just needed the big packet.
- *The boy asked the staff where he could find the product.* [Neutral]
- *The boy was planning to cook an Italian dish for his flatmates.* [No Update]
- *The boy was planning to cook a typical Arabic dish for his flatmates.* [Update]

After few minutes of searching, the young man found the packet of **couscous**.

➢ The young boy bought some camembert cheese. [No]

89. **The flowerpot** *shoots/worms*
This is my favourite season: spring.
I love it because everything is in bloom and it is colourful everywhere.
Today I saw something new in one of my flowerpots.
- *I called mum to ask if I should give it any special treatment.* [Neutral]
- *Small green things could be seen on the surface of the soil.* [No Update]
- *Small, smooth pinky-brown creatures were wriggling about in the soil.* [Update]

My mother came and saw the tiny little **worms**.

➢ It was colourful everywhere because it was spring. [Yes]

90. **The homework** *scissors/knives*
Hard-working Daniel brought his homework back from school.
He was learning how colour and cut out different shapes.
He coloured in the outline of tractor in yellow and carefully cut it out.
- *Her mother was next to him watching her son's new ability.* [Neutral]
- *He picked up the tool to cut out the drawing of the tractor.* [No Update]
- *He took the blade to cut out the drawing of the tractor.* [Update]

The child had finally succeeded in learning to use the heavy **knives**.

➢ Daniel had drawn a brown tractor. [No]