Reading between the lines

The activation of background knowledge during text comprehension

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This paper presents an overview of the activation of background knowledge during text comprehension. We first review the cognitive processes involved in the activation of inferences during text comprehension, stressing the interaction between text and reader in the construction of situation models. Second, we review evidence for embodied theories of cognition and discuss how this new framework can inform our understanding of the nature and role of background knowledge. We then review the neuropsychological data on the activation of background knowledge during text comprehension. Finally, the paper presents existing and future challenges in researching the role of background knowledge both at a conceptual and a methodological level.

Keywords: embodied cognition, narrative text comprehension, neuropsychology of narrative, sensorimotor representations, situation models

1. Introduction

Understanding written texts is a highly complex skill that readers often take for granted while performing the task. To comprehend even the simplest texts, readers must engage in such intricate processes as feature recognition, lexical access, memory storage and retrieval, integration, updating, etc. What is most remarkable, and often not realized, is that the words on the page merely provide the scaffolding for the meaning of a text. The lion's share of a text's meaning is actually constructed by the reader. In fact, when analyzing the meaning units present in a text, readers usually amount to an incoherent and often inconsistent set of statements. Without

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the activation of the reader's own background knowledge, almost every text would be incomprehensible. Thus, the meaning of a text is not comprised of the words and phrases in the text, but rather develops through an interactive process between the reader and the text. The current paper presents an overview on this particular topic of text comprehension research.

In the following sections we review recent theoretical and empirical advances in our understanding of when and how background knowledge is activated during text comprehension. First, we review the current state of theoretical and empirical understanding of this topic. We explain what types of background information are activated during text comprehension, giving particular attention to when and how inferences are drawn. Second, we consider the emerging framework of embodied language comprehension and what this view tells us about the type of background knowledge that is activated during reading. The empirical evidence for this view is reviewed and its theoretical relevance to text comprehension is discussed.

Undoubtedly, the interaction between reader and text requires the study of the reader's hardware. Accordingly, the next section presents new developments in the neuroscience of text comprehension, discussing the brain areas involved in activating background knowledge during text comprehension. Specifically, we consider the extent to which empirical research on this topic has helped to resolve controversy regarding the activation of background knowledge, as well as the strengths and weaknesses of current neuroscientific methods.

Finally, we evaluate current and future challenges in studying the activation of background knowledge during text comprehension. Although valuable observations and predictions have surely resulted from existing paradigms, we discuss strengths and weaknesses of current methodological approaches, and provide suggestions for better testing the reader-text interaction during text comprehension. We conclude with an integrated discussion of current advances and future challenges in the study of background knowledge activation from an embodied language comprehension perspective.

2. Background knowledge and discourse comprehension

2.1 Mental models of text comprehension

When comprehending a text, it is generally agreed that readers form a mental representation (or a mental model) of the text that is composed of different levels (Graesser, Singer, and Tabasso 1994; van den Broek, Young, Tzeng, and Linderholm 1998). At a *surface* level, for a short period of time, the exact words and the syntax are represented; at a *textbase* level, explicit text propositions and elements

needed for text cohesion are included; the final level, the *situation* level, discussed here, includes the situation that is conveyed by the words and the sentences in the text (Zwaan, Langston, and Graesser 1995). This level of representation includes information about the people, settings, actions and events either described explicitly or implied by the text (Garnham and Oakhill 1996; Zwaan and Radvansky 1998). Of special relevance is the fact that readers mentally represent information that is not explicitly mentioned in the text, but derived mainly from the process of *inference making* (Graesser et al. 1994; McKoon and Ratcliff 1992).

An important aspect of inference making relates to the fact that readers combine different sources of information to construct a situation model (Graesser et al. 1994; van den Broek et al. 1998). Readers activate previously acquired knowledge that is stored in long-term memory and combine it with information explicitly mentioned in the text (Gernsbacher 1997; Kintsch 1998). Importantly, readers go beyond mere linguistic processes when comprehending text. For example, from the sentence "We got some beer out of the trunk. The beer was warm" (from Haviland and Clark 1974), readers might infer that "it was a sunny day". This inference derives from the information provided in the text as well as common knowledge about what happens when you leave your car in the sun. The latter information is not presented in the text, but combining information from the text and from previously acquired knowledge enables readers to form a mental model of the situation and consequently comprehend the text.

A great deal of research has been directed towards investigating the generation of inferences at different moments in the comprehension process, mainly in the course of comprehending the text (i.e., while reading). Researchers have consequently differentiated *off-line* and *on-line* inferences. Off-line inferences are those made at retrieval, i.e., subsequent to reading, whereas on-line inferences are made during comprehension, i.e., while reading (Graesser et al. 1994). The main controversy regarding such a distinction concerns inferences that may or may not be generated while reading. Several theories have been advanced to account for research findings focused on this particular aspect of inference generation (see Graesser et al. 1994). Two of these theories, *the constructionist approach* and *the minimalist approach*, deserve further mention as they make clear and distinct predictions.

2.2 The constructionist approach of text comprehension

The core principle underlying the constructionist approach is one of search-after-meaning. This principle stipulates that people naturally attempt to construct meaning from texts, social interactions, and perceptual input (Bartlett 1932; as cited in Graesser et al. 1994). The search-after-meaning process is inevitably bound to the notion of *coherence*. Readers mainly draw inferences that enable them to

establish or maintain local and global coherence. Inferences establish or maintain local coherence through connections between adjacent text constituents, whereas those establishing or maintaining global coherence connect most constituents of a text by one or several deeper features, such as the general theme, the main point, or the moral of the text (Graesser et al. 1994).

Readers abandon the search-after-meaning process under several conditions, however (Graesser et al. 1994). First, if readers consider the text to be completely lacking in global coherence, no effort is made to resolve that lack of coherence. Second, if readers do not possess the relevant knowledge, they are not able to resolve breaks in coherence. Finally, if readers' goals do not require them to build a complex situation model, no effort is made to do so.

2.3 The minimalist approach to text comprehension

According to this approach, if readers do not adopt a specific goal-directed strategy of reading, the number of inferences made while reading is limited (McKoon and Ratcliff 1992). In situations like reading a magazine on a plane, people would more often engage in minimal processes. If readers' processes are guided by specific goals (e.g., the desire to learn new information from the text), the minimal representation that has been automatically constructed enables readers to establish a more elaborate representation of the text. McKoon and Ratcliff (1992) claim, however, that only inferences needed for local coherence and those based on information that is *readily available* are made automatically. Readily available information has its roots in either long-term memory and/or in the text. According to this view, inferences needed for global coherence are not made while reading unless they are based on information that is readily available.

2.4 Constructionist vs. Minimalist: A relevant dichotomy?

Both the notion of *readily available* information and the dichotomous distinction between minimalist and constructivist processes are questionable for several reasons. First, it can be argued that in most cases, if not all, background knowledge *is* needed to maintain coherence. Indeed, it has been argued that even automatic inferences in a minimalist approach require constructive processes (Garnham 1992). In the sentence "John blamed Bill because he spilled the milk", the automatic referential inference predicted by the minimalist position can only be made using knowledge about the rather unpleasant nature of spilling milk and about the specific circumstances causing somebody to blame somebody else. We therefore claim that the important question is not whether information on which to base the inference is readily available, but how background knowledge and textual

information may interact to generate (complex) inferences. This is, or should be, central to text comprehension research. The following sections address this issue with two separate illustrative areas that have not yet received great attention: *gender and emotion inferences*. The first area reflects the complex interaction between general knowledge and textual features, whereas the second demonstrates that background knowledge also activates perceptual features that may subsequently be integrated in readers' mental models.

2.5 Inferences about the gender of the protagonists

When reading a text about a protagonist whose gender is not explicitly stated, readers still include the protagonist's gender in the mental model of the situation (Carreiras, Garnham, Oakhill, and Cain 1996). That is, readers infer the gender. For example, when reading the sentence "The soldiers were running through the woods", it is very likely that readers form a representation that mostly includes *men*. Such a representation is automatic, and, in English, is based on stereotypical information (e.g., Garnham, Oakhill, and Reynolds 2002; Oakhill, Garnham, and Reynolds 2005). In languages that are grammatically gender marked, such a process becomes more complicated. In French, for example, to refer to a male student, the grammatical masculine form is used (i.e., *un étudiant*) and to refer to a female student, the feminine form is used (i.e., *une étudiante*). When a group of people is referred to, in French, as well as in other languages such as German and Spanish, the *masculine* plural form is used (i.e., *les étudiants*), and is not supposed to be interpreted as masculine, but rather as *generic*, referring equally to men and women. Readers are supposed to ignore the textual features when forming a mental representation of gender.

Some studies (e.g., Gygax, Gabriel, Sarrasin, Oakhill, and Garnham 2008) have questioned the validity of such a generic interpretation by assessing whether in German and French, gender inferences are based on background knowledge, as in English, or on the grammatical features (i.e., the masculine). More specifically, Gygax et al. (2008) directly evaluated the interaction between background knowledge and textual features. They found that in both French and German, when referring to a group of people, readers automatically build a male biased representation, independently of the stereotype portrayed by the role names. In French and German then, contrary to English, gender inferences are principally based on textual information, leaving very little influence to background knowledge.

Gabriel and Gygax (in press) furthered this finding by investigating whether, in some situations, textual features could be overridden by background knowledge in constructing a representation of gender in grammatical gender marked languages. They focused on Norwegian, which, although grammatically gender

marked, presents a very interesting particularity. Since the 1970's, in Norwegian, the feminine form has been officially abandoned for the purpose of establishing a true *gender-neutralized* masculine form (Norsk Språkråd 1997). To refer to a group of people, even if exclusively constituted of women, the masculine form is used. Gabriel and Gygax (in press) demonstrated that such a policy had only partly diminished the impact of the grammatical mark of gender. Indeed, although stereotypical information was influential in the construction of gender representation for male and female stereotyped role names, a textual feature (i.e., the masculine) was predominant for the construction of a gender representation of neutrally stereotyped role names (e.g., musicians).

In all, these results have two important implications. First, even when gender is not explicit in the text, a representation of gender is constructed while reading. Second, such a representation is either based on textual information or on stereotypical information depending on the grammatical properties of the role names and the social policies regarding language use. When no specific policies have been implemented and grammatical marking is present, it is based on textual information, as in French and German. When there are no textual features, it is based on stereotypical information, as in English. When specific language policies have been implemented, as in Norwegian, both stereotypical information and textual features are influential, showing an interesting interaction. Most importantly, and as stressed by Gabriel, Gygax, Sarrasin, Garnham, and Oakhill (2008), the influence of textual features in the construction of a representation of gender can never really disappear.

Although these aforementioned studies demonstrated that stereotypicality had little influence on the representation of gender when grammatical features were present, Schneider, Gygax, Wagner-Egger, Parris, and Kuhn (2008) further investigated stereotypical influences using a somehow different approach. Based on the notion of *embodied cognition*, which will be more thoroughly addressed later in this paper, they investigated whether *visual-spatial* representations would influence the construction of a mental representation of gender. Participants were presented with role names, in the masculine form (Experiment 1) or in both the masculine and feminine forms (Experiment 2), above or below a fixation point on the screen, and were asked to determine whether those role names were most likely occupied by *men* or *women*. Based on the idea that power is spatially represented (Schubert 2005) and that there are clear indications, in a discriminatory fashion, that women are considered by some as less powerful (Pratto, Sidanius, and Levin 2006), Schneider et al. hypothesized that participants, especially those holding sexist beliefs, would respond with *men* more often and faster when role names were presented above the fixation point, and with *women* more often and faster when the role names were presented below the fixation point. Although the results did not show the expected *visual-spatial* effect associated to gender, participants

were still faster to respond *men* when a stereotypical male role name of *high status* (e.g., *surgeon*) was presented above the fixation point then below it, and vice versa for *low status* stereotypical male role names (e.g., *technician*). There were also clear signs that participants responded more often *women* when the role names were considered of *low status* and more often *men* when role names were considered of *high status*, but this was independent of their spatial position. The interpretation of these latter results goes beyond the scope of this paper, but importantly, there was initial evidence of a spatial representation of male stereotypical role names, depending of the status of the role name.

In summary, the construction of a representation of gender is an interesting case, as it provides a genuine basis for the study of the interaction of textual features and background knowledge in inferential processes.[1] It is also interesting in terms of social representations and their impact upon the (perceptual) nature of the content of mental models. We next present the case of a different type of inference, which also stresses the perceptual nature of mental models.

2.6 Inferences about the main protagonist's emotional status

Early work on emotion inferences suggested that when reading narrative texts about a main protagonist in a situation eliciting an emotional reaction, readers infer the main protagonist's emotional state automatically and explicitly (e.g., Gernsbacher, Goldsmith, and Robertson 1992). When reading a story about a protagonist who lost his job, readers activate background knowledge about what happens when someone loses his or her job, and include the information as specific as *sad* in their mental model of the situation. Such specificity of inference has been further supported by other research on emotion inferences (e.g., de Vega, Díaz, and León 1997; Gernsbacher, Hallada, and Robertson 1998) and also by research on characters' trait inferences (Rapp, Gerrig, and Prentice 2001), which indicates that readers form a rather specific trait-based model of narrative protagonists.

Some authors (Gygax, Garnham, and Oakhill 2004; Gygax, Oakhill, and Garnham 2003) have questioned such a notion of specificity, suggesting that when reading a text, there is no need for the readers to activate complex background information and incorporate specific emotions in their mental representations, and that a more *superficial*, and perhaps more *concrete* representation of emotion will suffice to guide the reading process. Gygax et al. (2008) further this idea by showing that under normal reading circumstances, readers include behavioral elements that are perhaps more simple to retrieve from background knowledge and more easily shared by different modes of representation, in their mental model of the situation (e.g., *cry*, *clench your fist*). They argued that such information could still be interpreted as part of an emotion construct.

Put differently, Gygax and colleagues wanted to show that under normal reading circumstances, readers do not *need* a deep, complex representation of rather abstract emotions to comprehend the text. Readers simply activate more concrete information to be incorporated in their mental representation of the text. This information forms the basis for more complex and elaborate emotional inferences. In a sense, readers activate some elements pertaining to the main character's emotional status, and such information forms what can be defined as a shallow or underspecified representation of emotions. This parallels the idea found in research on text comprehension that underspecified representations of text are often perfectly acceptable (e.g., Sanford and Graesser 2006), and *good enough representations (*Ferreira, Bailey, and Ferraro 2002*) help to economize the comprehension process*.

It may be the case that readers' easily-activated background knowledge on emotions is mostly composed of physical elements, or elements pertaining to movement. Lamontagne-Mueller, Gygax, Hauert, and Seiler (2007) found some supporting evidence for this explanation by showing that readers activate some perceptual or visual-spatial traces of the character's body posture/movement when reading emotion situations. In the same line of thinking, others have demonstrated that the construction of a situation model incorporating predictive inferences was disrupted by a concurrent visual-spatial memory task (Fincher-Kiefer and DíAgostino 2004). This clearly shows that situation models are not amodal, incorporating verbal as well as perceptual information.

2.7 Concluding comments

Reading processes appear to be driven by readers' general need to establish and maintain a certain understanding of the text. Readers build a mental representation of the text based on inferences that contribute to text coherence by identifying the connections among ideas, and inferences that call for the use of background knowledge (see Singer and Remillard 2004; Schmalhofer, McDaniel, and Keefe 2002). The nature of such an interaction has proven to be a true challenge for text comprehension researchers, as (1) the interaction between the two sources is complex and varies from situation to situation, and (2) the background knowledge that is activated can be underspecified and multimodal in nature. Emotion and gender inferences are typical cases that reflect these issues, which will be further discussed in the following section.

3. Embodied Text Comprehension

In recent decades, the field of cognitive psychology has seen a shift away from symbolic, amodal cognitive systems and towards embodied theories of cognition. While traditional views (Fodor 1983; Pylyshyn 1986) assumed a conceptual system that processed symbolic units that were arbitrarily related to their referents (the word *dog* does not look, sound, smell, taste, or feel like an actual dog), embodied theories have pushed to explicitly integrate the body and its perceptual-motor systems into conceptual models. According to this new embodied framework, language and conceptual representations are instantiated in the same systems that are used for perception and action. This means that when comprehenders process language, they partially reactivate previous traces of experience that are distributed across multiple perceptual and motor modalities in the brain.

This recent embodied framework of language comprehension can therefore help to better articulate our understanding of the type of background knowledge that is activated during text comprehension. Because the embodied framework predicts that perceptual-motor representations are routinely activated during language comprehension, reading a text should activate information about how the described characters, things, and places should look, sound, smell, and feel (in both the emotional and tactile senses). According to this framework, even potential motor responses to described situations are activated. The evidence for these claims is reviewed below.

Perceptual-motor representations in language comprehension are conceptualized as activations of experiential simulations of a described situation (Barsalou 1999; Zwaan and Madden 2005). There is a growing body of evidence that the representations underlying language comprehension are grounded in our perceptual and motor systems (Glenberg and Kaschak 2002; Hauk, Johnsrude, and Pulvermüller 2004; Kan, Barsalou, Solomon, Minor, and Thompson-Schill 2003; Kaschak et al. 2005; Klatzky, Pellegrino, McCloskey, and Doherty 1989; Madden and Zwaan 2006; Solomon and Barsalou 2001; Zwaan, Madden, Yaxley, and Aveyard 2004; Zwaan, Stanfield, and Yaxley 2002; Zwaan and Taylor 2006). Although both systems are most often incorporated in a given representation, these systems are often studied separately, and as such, demonstrations that language comprehension evokes perceptual representations of the described situation will be considered first, and evidence for the activation of motor representations during language comprehension will be discussed thereafter. Finally, supporting evidence from imaging studies is mentioned before turning to the implications of the embodied framework of language comprehension on the activation of background knowledge during text comprehension.

3.1 Perceptual representations

A study by Zwaan and colleagues (Zwaan et al. 2002) has shown that comprehenders routinely activate perceptual representations of objects described in short sentences. In this study, participants heard a sentence describing an object in a particular location, such as "In the sky there was an eagle," and were asked to decide whether or not a subsequently pictured object was mentioned in that sentence. On experimental trials, the subsequently pictured object was always the object mentioned in the sentence, requiring a 'yes' response. However, the shape of the pictured object could either match or mismatch the contextual constraints of the preceding sentence. For example, in the sentence, "There was spaghetti in the pot", a picture of cooked spaghetti would be a matching picture, whereas a picture of uncooked spaghetti would be a mismatching picture. Responses were faster for pictures that perceptually matched rather than mismatched the contextual constraints of the sentence, providing support for the idea that perceptual information is incorporated in language representations. Even when participants did not have to respond as to whether the pictured object was mentioned in the sentence, but rather simply name the pictured object, pictures that perceptually matched rather than mismatched the contextual constraints of the sentence yielded faster naming responses. This effect has been shown across age groups as well as across skill levels (Madden and Zwaan 2006). Furthermore, similar studies have also demonstrated that comprehenders routinely represent other perceptual aspects of described entities, such as the direction of motion of objects (Zwaan et al. 2004) and the orientation of objects (Stanfield and Zwaan 2001).

In addition, Pecher, Zeelenberg, and Barsalou (2003) have demonstrated that perceptual representations underlie conceptual language comprehension. In their study, switching from one modality to another incurred a switching cost, just as has been shown in perceptual processing tasks. Participants were faster to verify properties of concepts in a given perceptual modality if it was preceded by a trial in which the same perceptual modality was verified. For example, participants were faster to verify *BLENDER-loud* (auditory modality) if it was preceded by *LEAVES-rustling* (auditory modality) rather than *CRANBERRIES-tart* (taste modality). Only words were presented in the experiment, and participants were not instructed to engage in imagery. This study demonstrates how language comprehension is grounded in the perceptual processing system, and thus exhibits the same limitations and sensory-motor phenomena that have been shown for purely perceptual tasks.

3.2 Motor representations

In addition to the evidence for perceptual representations, language comprehension has also been shown to engage motor representations. For instance, a study by Klatzky and colleagues (1989) demonstrated that motor patterns can facilitate the comprehension of language. Participants were faster to read and comprehend a sentence about throwing darts when they were first instructed to form their hand into the pinched fingers (dart-throwing) position. Activating the motor program for dart throwing serves to grease the wheels for conceptual processing of a sentence about throwing darts. For the motor pattern to be able to facilitate language comprehension, the two must be represented in the same system.

More recently, Glenberg and Kaschak (2002) have reported a related phenomenon called the action-sentence compatibility effect. In this study, participants were faster to make responses in the same direction as the actions described in sentences. For instance, participants were faster to move their finger from one button to another farther away from the body when sentences implied motion away from the body ("close the drawer"). This effect is consistent with language comprehension that is embodied, or grounded in action. The action sequences described in the sentences activate motor representations, and therefore are susceptible to interference from motor programs in the sensorimotor cortex. Furthermore, Zwaan and Taylor (2006; Experiment 4) have shown that the activation of motor representations during the comprehension of action sentences is rather immediate as it occurs during processing of the verb describing the action in question.

3.3 Imaging evidence

Research from brain-imaging studies also provides support for the embodied view of narrative comprehension. When action words and sentences are comprehended, motor regions of the brain are active (Hauk et al. 2004). Also, animal words have been shown to produce activation in the visual cortex, as animals are often viewed, while tool words have been shown to produce activation in the premotor cortex, as tools are often manually manipulated. Furthermore, reading threatening words has been shown to activate the amygdala, the brain region associated with processing human emotions, such as fear. Findings such as these suggest that modality specific representations are activated during narrative comprehension.

3.4 Implication of an embodied view on text comprehension

Research on embodied language comprehension demonstrates that reading words and sentences activates perceptual-motor representations in the same systems that

process perception and action. This emerging framework proposes that the various types of inferences can be re-defined in terms of perceptual and motor simulations. This recent embodied framework of language comprehension can therefore help to better articulate our understanding of the type of background knowledge that is activated during text comprehension. When we simulate described situations, we activate supplementary information, such as affordances, emotional responses, and typical situational constrains (agents, patients, locations, objects, actions) that all aid in the comprehension process.

As mentioned before, comprehending a text involves a dynamic interaction between text and reader. Thus, the type of background knowledge that is activated varies, depending on the individual who is reading. Accordingly, the embodied framework predicts that the same text would yield different simulations for different people, based on their experiences with the described entities and events. For instance, a simulation of "the top of the refrigerator" for a very tall person would likely include a view of the upper surface of the refrigerator and any dust or whatnot that is on it, whereas the same simulation for a short person would probably not include a view of the top surface of the refrigerator. The stronger prediction follows that if representations are reactivations of perceptual-motor experience, then a person can only represent that which he or she has already experienced, or combinations thereof. While combinations of previous experiences afford ample representational possibilities, this does constitute certain limitations (e.g., infinite time/space, multidimensionality).

It should be noted that a simulation activated through reading a text is presumably much less complete than actual perception or action experiences, as it only partially reactivates memory traces of perceptual and motor experience. Thus, the resulting representations are not as perceptually specified and vivid as actual experience. This idea is consistent with the idea of underspecified representations of text mentioned in the previous section on inferences (e.g., Sanford and Graesser 2006; Ferreira, Bailey, and Ferraro 2002). Although the activation of perceptual-motor representations is partial or schematic in comparison to actual experience, it is nonetheless instantiated in the same systems as those used for perception and action. Therefore, it serves as a mechanism for grounding the background knowledge that is activated during language comprehension in our bodily experience. This has been demonstrated through behavioral experiments on perceptual representations and motor representations, but also through imaging the activity of brain areas responsible for these representations. The following section will provide a more specific understanding of the various brain areas involved in the activation of background knowledge during text comprehension.

4. Neuroimaging studies of text comprehension

Recent development in the study of text comprehension has been characterized by the use of brain-activation measures such as *functional magnetic resonance imaging (fMRI)* and *positron emissions tomography (PET)*. These types of neuroimaging techniques have enabled us to identify changes in neural activity in particular brain regions by measuring blood flow variations during text comprehension (Bookheimer 2002; Ferstl 2007; Gernsbacher and Kaschak 2003; Mar 2004). The fMRI methodology is a non-invasive technique that uses nuclear magnetic resonance to render images of the brain's blood flow during the processing of particular stimuli, whereas the PET technique is an invasive method in which a radioactive material is injected into the blood stream and later detected by an X-ray yielding a 3-D image. Both techniques capitalize on the fact that active areas of the brain recruit a higher level of blood flow. Although different designs can be used, most experiments are based on a subtraction approach in which the brain activations elicited by two more or less similar tasks are directly compared.

Ferstl, Rinck, and von Cramon (2005), for example, used event related fMRI to map the neural correlates of text comprehension processes in different contexts. They compared the comprehension of stories which contained inconsistencies in chronological or emotional information with consistent versions of the same stories to study the effects of processing inconsistent information. The researchers observed activation in the left precuneus and a bilateral frontoparietal network for chronological consistent information whereas consistent emotional information revealed activation in the ventromedial prefrontal cortex and the extended amygdaloid complex. The integration of inconsistent chronological information engaged the lateral prefrontal cortex bilaterally, whereas the integration of inconsistent emotional information required the dorsal frontomedial cortex. The authors concluded that updating the situation model was not a unitary process but rather depended on the specific requirements of the text. These results, especially those regarding the activation of emotion centers, are particularly relevant to the activation of background knowledge during language comprehension. Most importantly, those activated brain regions have been known to be activated during emotion *experience* (see Buchanan 2007), suggesting a simulation process as predicted by the embodied cognition framework.

Neuroimaging studies such as this one show that several brain regions are essential to the activation of background knowledge. In the following sections, the contributions of these brain regions are discussed. First, the evidence on the right hemisphere during comprehension is reported. Secondly, the crucial role of executive functions is evaluated by analyzing the lateral prefrontal cortex. Finally,

the roles of the anterior temporal lobe and of the fronto-medial cortex, specific to text comprehension in an inconsistent context, are also discussed.

4.1 The role of the right hemisphere in text comprehension

Although the right hemisphere is known to be involved during text comprehension, its role is still unclear (Mar 2004; Ferstl 2007). Several studies have shown a contribution of the right hemisphere in activating certain inferences and predictability in specific contexts (Beeman, Bowden, and Gernsbacher 2000; Ferstl et al. 2005; Long and Baynes 2002; Mason and Just 2004; Nichelli et al. 1995; Roberston et al. 2000; St. George, Kutas, Martinez, and Sereno 1999; Virtue, Haberman, Clancy, Parrish, and Beeman 2006; Vogeley et al. 2001). For example, St. George et al. (1999) showed that right hemisphere activation was stronger for untitled than titled stories in their fMRI study. However, other studies have mainly reported left-dominant activation (Ferstl and von Cramon 2001; Fletcher et al. 1995; Maguire, Frith, and Morris 1999; Virtue et al. 2006). Some have suggested (e.g., Mason and Just 2004) that while the right hemisphere appears to be involved in activating certain inferences, the left hemisphere may be involved in selecting and integrating these inferences into the discourse structure.

From these studies it can be gleaned that both the left and the right hemisphere are necessary for the elaboration of meaning from linguistic input. This indicates that there should be a bilateral semantic processing in order to process complex linguistic units (see Virtue et al. 2006). The extraction of meaning from texts requires from readers the use of their background knowledge to draw pertinent inferences and activate adequate memory codes for the situations referred to in the texts. However, whereas the left hemisphere seems to deal with semantic concepts closely linked to the input, the right hemisphere focuses on broader semantic concepts that are implied by and related distantly to the linguistic input. This functioning of the right hemisphere has been termed the Coarse Semantic Coding (Beeman 1998; Jung-Beeman 2005). The relevance of this hypothesis for the use of background knowledge lies in the fact that whereas specific knowledge seems to be activated by the left hemisphere, knowledge about related categories and concepts in a coarser interpretation of language seem to be done within the right hemisphere.

4.2 The role of lateral prefrontal cortex in text comprehension

Neuroimaging studies indicate that the prefrontal cortex seems to be important for the activation of background knowledge during text comprehension. Whereas Broca's area, within the inferior prefrontal cortex, is involved during phonological

and syntactic processes at the sentence level (see Bookheimer 2002), deeper text comprehension processes activate the frontal lobe region, the center of different executive functions such as inhibition, monitoring, or sequencing (Crozier et al. 1999; Ferstl and von Cramon 2001; Grafman 2002; Roberston et al. 2000). Cognitive models of text comprehension also locate encoding, retrieval, and integration processes in the prefrontal cortex, more specifically in the dorsolateral prefrontal cortex. Grafman (2002) proposed that the prefrontal cortex is responsible for the processing of structured and sequential events that are goal oriented and schematic. More specifically, the functions attributed to more specific areas of the prefrontal cortex, such as processing social event sequences (ventromedial prefrontal cortex) and predictable event sequences (medial prefrontal cortex) appear relevant for text comprehension, especially the comprehension of narrative events. However, the exact function of these regions is not yet known (see Ferstl 2007; Zalla, Phipps, and Grafman 2002). In addition, the comprehension of texts involves strategic memory retrieval processes, including the monitoring and manipulation of the contents of working memory (middorsolateral frontal cortex), as well as the maintenance of cues for long-term memory retrieval and encoding (ventrolateral frontal cortex), and the processes of rejecting or accepting the products of memory retrieval (the prefrontal cortex).

Other studies (Ferstl and von Cramon 2002; Ferstl et al. 2005; Frith and Frith 2001; Saxe, Carey, and Kanwisher 2004; Vogeley et al. 2001) have related the dorso-medial prefrontal cortex to theory of mind processes. These refer to the ability to attribute people's actions to their beliefs, motivations and goals. For example, Fletcher et al. (1995) collected PET data asking participants to read stories requiring the attribution of mental states to characters and showed that comprehending narrative events involved the inclusion of the protagonists' states of mind, including their goals and emotions (Mar 2004; van den Broek 1994), in their mental representations while reading. Thus, the dorso-medial prefrontal cortex plays an important role in the activation of background knowledge during reading.

4.3 The role of the anterior temporal lobe and of the fronto-medial cortex in text comprehension

Several studies have shown that the anterior temporal lobes are activated during the integration of incoming words into an existing semantic representation. More precisely, the local detection of inconsistencies has been found to be related to the activation of a right anterior temporal region (Beeman 1993, 1998; Roberston et al. 2000; St. George et al. 1999) and posterior temporal areas (Kircher, Brammer, Andreu, Williams, and McGuire 2001; St. George et al. 1999; Schmithorst, Holland, and Plante 2006). However, Humphries, Willard, Buchsbaum, and Hickok

(2001) have shown evidence of activation of the left anterior temporal lobe while processing events in the auditory modality.

Various processes associated with text comprehension, such as semantic, executive, phonological, and affective processes, have been shown to be vulnerable to selective impairment. For instance, patients with dysexecutive functioning associated with prefrontal cortical damage fail to understand texts cohesively (Ferstl, Guthke, and von Cramon 1999; Mar 2004; Troiani, Ash, Reilly, and Grossman 2006). Zalla et al. (2002) showed that patients with prefrontal lesions had problems with both on-line inference processes and with extracting the sequential order of story events. Research on lesion patients also confirmed the participation of the frontal lobes and right hemisphere areas in sequencing events during text comprehension.

4.4 Strengths and weaknesses in neuropsychological methods

Whereas the high spatial resolution of fMRI and PET has been extremely useful with respect to localizing the specific brain areas that contribute to language comprehension, they are not without their limitations. These techniques rely on levels of recruited blood flow, and thus are only indirect measures of neural activity. The temporal resolution of these measures is rather low, as blood is only recruited into brain areas *after* that area has become active and used up existing supplies. Likewise, in addition to the high level of invasiveness, the temporal resolution of the PET methodology is further constrained as the radioactive agent decays rapidly, and tasks that require more time and elaboration, such as text comprehension, become difficult to monitor. In light of these temporal limitations, it is important to supplement fMRI and PET findings with other techniques, such as electroencephalogram recordings and transcranial magnetic stimulation.

Electroencephalogram (EEG) recording is a non-invasive technique to record brain electrical impulses by means of several electrodes which are placed on the scalp. Time-locking this electrical recording to a specific stimulus event yields an event-related potential (ERP), which has been especially informative for language research. A particular strength of this methodology is its highly accurate temporal resolution, indeed better than fMRI and PET. However, the spatial resolution of EEG recordings is poor in comparison to those of fMRI and PET. Thus, EEG recordings can be combined with imaging data to obtain high spatio-temporal assessments of brain activity during text comprehension (see Hagoort, Hald, Bastiaansen, and Petersson 2004). Likewise, transcranial magnetic stimulation (TMS) is another measure that offers high temporal resolution. TMS is a non-invasive method to stimulate neuronal groups in the brain by using a wire coil placed close the head that releases weak electromagnetic currents. Finally, the emerging

methodology of magnetoencephalography (MEG) is a fairly recent advancement in the study of language processing. This technique measures the magnetic fields produced by electrical activity in the brain using extremely sensitive magnetometers that can pick up small magnetic fields. Both the temporal and spatial resolutions of MEG are better than those yielded by fMRI and EEG (see Baillet, Mosher, and Leahy 2001). Given MEG's advantages, it presents a very promising means to identify the brain areas activated when embodied background knowledge is used during text comprehension.

4.5 Concluding comments

This section presents neuroscientific evidence supporting the idea that text comprehension requires the activation of background knowledge. In particular, this section highlights how different brain areas are activated immediately and in a distributed network so that memory, inferences, and mental simulations can be performed during the comprehension process. Neuroscience methodologies, with all of their strengths and weaknesses, have revealed much about the activation of background knowledge during text comprehension and the underlying brain areas implicated in this process. However, despite the significant progress that has been made in this realm, fully understanding the relative neural contributions of components of the extended language network remains one of the clear challenges for future research. The following section addresses further challenges that lie ahead for the study of text comprehension.

5. Methodological and conceptual challenges

The study of text comprehension has employed various methodologies to reveal the cognitive processes and the neural systems that underlie language comprehension. The present section discusses important limitations and conceptual challenges to current approaches, as well as potential avenues for future research. First, current strengths and limitations of behavioral methods in understanding the role of background knowledge during language comprehension will be discussed. Next, the possible benefits of a more naturalistic approach to understanding how background knowledge can be used to enhance comprehension are addressed, followed by the educational implications of this type of approach. Finally, existing and future challenges to the embodied language comprehension framework are considered.

5.1 Behavioral methods

In language research, behavioral experiments have been the primary tool in understanding how people process sentences and texts. Because *offline* methods tap readers' situation model *after* reading, these measures have been particularly useful in understanding the contents and nature of the situation model that has been constructed upon reading. In these types of tasks, researchers measure reading times of whole sentences or texts, responses to probe words, pictures, or questions, recall accuracy and content of stories, text summaries, and responses to questionnaires, to name a few. While offline methods have provided invaluable information about the comprehension process, it is becoming increasingly important to investigate *online* processes to gain a better understanding of exactly how the situation model is constructed step by step. Online measures, such as eyetracking, word by word reading time measures, within-sentence probe designs, and concurrent interference tasks, tap the ongoing comprehension process, rather than the end product of this process.

Research from the embodied framework has been particularly fruitful in providing new online methods and improved tools to investigate the activation of embodied background knowledge. For example, researchers have employed visual adaptation tasks (Glenberg, Harnad, Goldstone, Wiemer-Hastings and Zwaan 2005), visual and manual rotation tasks (Zwaan and Taylor 2006), perceptual motion interference tasks (Kaschak et al. 2005) and the marble moving task (Casasanto and Lozano 2007), to mention just a few. Many of these tasks are designed to test the interference or facilitation of concurrent perceptual-motor stimuli on language comprehension. For example, Casasanto and Lozano (2007) investigated whether ongoing motor actions affected the spatial content of literal or metaphorical stories (Experiment 1). Participants were asked to tell stories while moving marbles from one box to another repeatedly in a specified direction (i.e., upward, downward, leftward, and rightward). The researchers found that marble movements, although irrelevant to storytelling, did influence participants' verbal fluency. Movement direction (e.g., upwards) that were congruent with the spatial schema implied by the story (e.g., literal: *my rocket went higher*; metaphorical: *my grades went higher*) increased participants' verbal fluency. Likewise, a deficit was observed when the movement direction mismatched the direction implied in the story. These results suggest that not only concrete concepts, but also metaphorical concepts are tied to perceptual-motor representations. This avenue of research on abstract concepts will be further discussed in the section on challenges to the embodied view.

Another particularly useful tool in online language comprehension research is the eyetracking methodology, in which eye movements are monitored as participants view linguistic or pictorial stimuli. The position of the eyes can be a revealing

window into what information is currently being processed. For instance, Chambers, Tanenhaus, Eberhard, Filip, and Carlson (2002) monitored participants eye movements while they followed instructions (*Put the cube inside the can*) to manipulate real objects in a workspace. The researchers found that visual attention was limited to objects that afforded the constraints of the instruction (containers) and furthermore, to objects that afforded the constraints of the physical situation (containers that are large enough). This suggests that the comprehension system rapidly integrates linguistic information with situation-specific constraints and background knowledge about affordances. This type of background knowledge taps our physical experiences and is consistent with the idea of perceptual-motor representation during language comprehension.

5.2 A naturalistic language approach

The study described above is rare in its use of a rather naturalistic task. Although following directions to manipulate objects in an experimental workspace is not something we do every day, the design nonetheless represents an attempt to bring language research into a more real-world domain of listening and acting. This raises the issue of ecological validity in language comprehension research, which is a general criticism of many studies. Indeed, many studies, and especially studies in the embodied language comprehension framework, employ single words or sentences as experimental stimuli, which is not at all how language is experienced in the real world. A future challenge for the embodied language comprehension framework lies in expanding experimental stimuli to include larger texts and discourse, while maintaining the experimental control and precision that are required to test the specific mechanisms of language comprehension.

In moving away from single word experiments, one immediately faces the issue of word combinations in the activation of background knowledge. For instance, even when stimuli are restricted to noun-verb combinations, it already becomes difficult to discern whether certain types of background knowledge are activated by the noun, the verb, or a combination of the two. While verbs alone have been shown to activate much information concerning typical agents, patients, and instruments/tools (Ferretti, McRae, and Hatherell 2001), combinations of verbs and nouns (*girl-ride vs. man-ride*) have been shown to produce different activations of background knowledge (*carousel vs. motorcycle*) which are clearly due to the word combinations rather than the individual words themselves (Kamide, Altmann, and Haywood 2003). Even small inflections of a given verb in verb-noun combinations (*served customer vs. serving customer*) can produce different interpretations based on background knowledge about typical agents and patients in events (Ferretti, Gagné, and McRae 2003). This interaction between words presents an interesting

avenue of research, yet also a challenge for embodied research, and one that becomes even more interesting and challenging when larger texts are considered. Although single word and single sentence experiments continue to be invaluable to the field of research, it is equally important to extend research designs to include larger texts for reasons of external validity.

Even when larger texts are used, however, a core criticism is that the texts used are generally "textoids", or texts created by the investigators and modified to control experimental variables that fit the research questions. Textoids do not capture the complexity of literary texts like tales and novels (Lorch and van den Broek 1997; van den Broek, Rohleder, and Narváez 1994). Also, conceptually speaking, the language that currently explains text comprehension is strongly biased by cognitive theories that pay relatively little attention to advances in literary studies and narratology. Consequently, a more accurate understanding of narrative texts themselves is a task that seems to warrant attention.

As an alternative to textoids, many researchers stress the importance of using more "natural" texts and reading situations in the study of text comprehension. These ideas have emerged through the support of psychological models conceptualizing narratology, literary theories, and semiotics (Segal 1995; Short 2001), as well as research proposals that try to capture psychological activity in everyday contexts. Such proposals have contributed to a more situated methodology for studying the comprehension of narrative texts. For example, González (2005) utilized observation and interview techniques to identify the way in which teachers lead a group of children towards the implicit information in texts and the formulation of inferences.

In addition, theories in social psychology account for the relationship between social cognition and narrative texts (e.g., Donahue and Foster 2004; Emmott 2003) and the social factors linked to language usage in everyday situations (e.g., Niedenthal, Barsalou, Winkielman, Krauth-Gruber, and Ric 2005). These theoretical contributions have led to the design of studies in which the influence of social variables on narrative comprehension can be measured (Kennan et al. 1990; Lorch and van den Broek 1997; Magliano 1999). For example, Magliano (1999) used verbal protocols (thinking aloud) and question-answering techniques to understand how readers elaborate inferences during text comprehension, a necessary cognitive process to connect background knowledge to the linguistic input. In these investigations, researchers use original narrative texts (i.e., naturalistic texts), which are the same sort of texts people read in everyday contexts. These types of methodological approaches that more closely resemble real reading situations pave the way for investigating the comprehension of texts in more applied settings, such as educational environments.

5.3 Educational implications

The psychological study of text comprehension contributes to the development of methodologies that promote the utilization of background knowledge during narrative text analysis in educational settings (Arroyave, Jiménez, Londoño, and Marmolejo-Ramos 2004; Marmolejo-Ramos 2004). Principally, it is argued that through the use of narrative texts in educational settings, high-level cognitive operations can be bootstrapped, and more situated psychopedagogical interventions can be modeled. This highlights important implications with respect to the emerging view of embodied language comprehension. Specifically, the use of experience-based knowledge, mainly sensoriomotor knowledge, can promote the comprehension of events (Marmolejo-Ramos 2007). For instance, classic experiments carried out by the Genovese School (Sinclair et al. 1985/1976; Sinclair and Bronckart 1972) demonstrated that children comprehended and produced short sentences with greater ease when they were permitted to manipulate toys representing the actions embedded in the sentences.

More recently, Glenberg and colleagues (Glenberg, Brown, and Levin 2007; Glenberg, Gutiérrez, Levin, Japuntich, and Kaschak 2004) extended the Genovese results by using texts instead of short sentences. In one of their experiments a group of young readers was asked to manipulate objects to enact the actions and characters referred to in a text, whereas another group was asked to re-read the text without manipulating the objects. Researchers found that the manipulation group performed better in a comprehension task where memory and inferences for the text were measured (Glenberg et al. 2007). These results support the idea that the active use of embodied background knowledge facilitates comprehension. This idea is also consistent with results of Gentaz and colleagues (e.g., Bara, Gentaz, Colé, and Sprenger-Charolles 2004) on young children's ability to learn about letters and shapes. Gentaz and colleagues have observed that children are better able to learn about letters and shapes when they have perceptual-motor experience of touching and drawing these letters and shapes. This constitutes yet another demonstration that meaning is better grasped when the situation referred to is grounded in the readers' sensory-motor experience with the world.

5.4 Challenges to the embodied view

The embodied language comprehension framework is not without its critics. Indeed, some researchers posit that much of the empirical evidence supporting the embodied view can likewise be explained through amodal representations. However, it is often the case that embodied theories *predict* these empirical results whereas amodal theories can only *explain* them post hoc. In addition, some critics

argue that embodied theories lack a precise explanation of the processes mediating language input and the activation of sensorimotor areas. Although the role of sensory-motor representations in the narrative comprehension process is not fully understood, progress is being made on this front (for a review see Fischer and Zwaan 2008). For instance, Madden and Zwaan (2006) have shown how sensory-motor representations can act as a mechanism for construing the contextually appropriate meaning or sense of a word during language comprehension. Likewise, Zwaan and Taylor (2006) have helped to delineate the timeline of activation of sensory-motor representations. Although research is underway in this area, it is clear that there is still much to be explained.

Mahon and Caramazza (2008) argue that the lack of precision in defining the mechanisms underlying sensorimotor activation leaves open the possibility that modal representations could mediate the interaction between linguistic information and sensorimotor activation. Indeed, it would be difficult for embodied theories to demonstrate that amodal representations are not being activated during language comprehension. Nevertheless, the inclusion of an amodal processing system does not undermine the embodied view; on the contrary, it may offer additional explanatory value that invites further investigation. It may be the case that the embodied system has older roots in the evolution of human cognition, and amodal symbol processing evolved at a later stage to further aid cognition and communication.

A further criticism of the embodied language comprehension framework is that it remains unclear how the working definition of embodied language comprehension presented thus far applies to abstract entities. A potential response to this criticism lies in metaphorical representation, in which case abstract concepts can be understood through a mapping onto more concrete concepts (e.g., Lakoff and Johnson 1980). Indeed, when people are asked to generate features for abstract concepts, they tend to relate abstract concepts to other concepts that are more perceptual in nature (Wiemer-Hastings and Xu 2005). In addition, there is recent empirical evidence demonstrating that specific bodily actions enhance people comprehension of metaphors (Wilson and Gibbs 2007). That is, the metaphorical phrase "push the argument" is comprehended faster when people perform a push movement previous to reading the phrase than when they perform a mismatching body movement or simply do not perform any movement. Although the metaphorical language of interest is often reduced to phrases that can be explicitly linked to perceptual and motor referents, this line of research presents a first step at addressing the problem of abstract representations within the embodied language comprehension framework.

Another approach suggests that abstract event descriptions may be understood in terms of more concrete physical events, without reference to metaphor.

Talmy's (1988) theory of force dynamics explains that we understand not only concrete events (*The bulldozer pushed the dirt across the lot*) but also abstract events (*Jenny convinced her husband to confess*) by representing their underlying patterns of physical forces (e.g., causing action, allowing rest) and relating them to our own physical and psychosocial experiences. In line with this theory, Madden and Pecher (2007) have demonstrated that abstract sentences are comprehended faster when they were preceded by concrete sentences or event animations of the same rather than different underlying force patterns, even though the abstract sentences had nothing else in common with the preceding sentence or animation. This provides a possible mechanism by which abstract events may be understood, namely in terms of the physical and psychosocial forces underlying the events. This view of grounding abstract concepts in more concrete and physical principles that are easier to understand is consistent with the research described earlier by Gygax and colleagues. These researchers demonstrated that emotional inferences often include concrete behavioral elements (e.g., *cry*, *clench your fist*) instead of more abstract emotional information, suggesting that comprehension of such complex emotional information is often reduced to what it feels like in the body to be angry, surprised, relieved, etc. This line of research provides yet another avenue to explore in representing abstract concepts within the embodied framework.

5.5 Concluding comments

The present section describes how current methodologies in the study of text comprehension have yielded many insights into how background knowledge is activated and used during language comprehension. However, new research questions are continually arising that require innovative methodological approaches, especially online measures of language comprehension. At the same time, researchers must strive to incorporate naturalistic approaches to the study of text comprehension into their studies. Meeting these research demands brings the promise of greater success in educational environments and other applied settings. Finally, several important criticisms of the embodied language comprehension framework were raised, but not without offering potential avenues of research to respond to these criticisms.

6. Conclusion

About forty years ago, linguists believed that readers constructed mental representations of a text that encompassed its exact words. Evidently, and as discussed at length in this paper, the role of background knowledge was clearly underestimated

in the construction of a representation of the situation portrayed in the text. The present article cites recent research on inference processing, embodied language comprehension, and neuroimaging studies of text comprehension, to demonstrate how background knowledge is as relevant a source of information as the words in the text themselves. Although these areas of research are promising in furthering our understanding of the interaction between background knowledge and textual features in the construction of mental representations, there remain considerable challenges to research in these domains. Nevertheless, the study of text comprehension has broadened our understanding of how people use their background knowledge to process texts, and at the same time has raised new questions that merit appropriate conceptualizations and suitable methodological approaches to form a clearer image of how texts are understood.

Note

1. Let us not forget, although it is not central here, that such a study also has great social implications. In Switzerland and France, for example, job advertisements are still often presented in the masculine form, taking for granted that readers will consider it as a generic form. As observed by Gygax et al. (2008), this is undoubtedly discriminatory to women.

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