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An Embodied Approach to Language:

The Role of Bodily Feedback in Discourse Processing

Oleksandr V. Horchak

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An Embodied Approach to Language:

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Do what you can, with what you have, where you are

Theodore Roosevelt

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Notes

The treatment of participants in all studies reported in this thesis was in accordance with the ethical standards of the American Psychological Association (see Standards 3.10 and 8.01 – 8.09 in the "Ethical Principles of Psychologist and Code of Conduct," APA, 2002)

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Resumo

Uma ideia-chave das teorias simbólicas é que a compreensão da linguagem advém da manipulação de símbolos amodais que descrevem condições perceptivas, motoras e emocionais, o que parece estar em contradição com a nossa capacidade de interação com o ambiente. Por exemplo, é difícil acreditar que os sistemas sensoriais corporais não estejam envolvidos no processamento da linguagem quando alguém descreve a sua última ida a um café como o Starbucks ou Tim Hortons através das seguintes palavras: aromático, deleitável, suculento, delicioso, fragrante, caloroso, acolhedor, confortável, arrebatador, pungente ou sensual. Em contraste com as teorias simbólicas, a aplicação da cognição incorporada na compreensão da linguagem defende que os símbolos amodais tornam-se significativos apenas através da nossa percepção e interação com os objetos e situações que esses objetos representam (Glenberg, 2010). Deste modo, o processamento da linguagem envolve sistemas corporais e neurais utilizados em experiências perceptivas, de ação e emocionais do mundo real. Aplicando esta conceptualização, a compreensão de uma frase como “ A empregada parece divertida quando entrega uma chávena de café recentemente moído e um scone a um senhor de meia-idade” requere o restabelecimento de informação perceptual para simular os objectos e os agentes descritos na frase (e.g., café, homem de meia-idade), informação perceptual olfactiva para simular o cheiro de um scone quente e de café recentemente moído, informação motora para simular como a empregada entrega o café ao senhor e, informação emocional para simular a sensação de divertimento da empregada.

A discussão acerca da importância da activação sensório-motora que ocorre durante a compreensão da linguagem inicia-se nesta tese com uma revisão bibliográfica sobre estudos empíricos focando o processamento da linguagem através da descrição de conceitos concretos e abstratos. Verificou-se que os dados de todos esses estudos convergem na conclusão que as representações incorporadas são necessárias para a compreensão. Simultaneamente concluiu-se que, na área do processamento da linguagem, ainda necessitam de ser abordados vários assuntos importantes, tendo-se destacado duas questões essenciais. A primeira é se a incorporação afecta a compreensão de eventos linguísticos abrangentes tais como o discurso. O interesse por esta questão foi inspirado por discussões prévias acerca da escassez de estudos sobre o papel de simulações de modalidade-específica durante a

compreensão de discursos (Fischer & Zwaan, 2008), bem como pela importância de testar a compreensão da linguagem a um nível mais global de discurso (Graesser et al., 1997; Sparks &vi Rapp, 2010). A segunda questão é se as representações incorporadas servem para afectar o processamento do discurso “offline”.

Após a revisão de evidências empíricas e teóricas que suportam a cognição incorporada, bem como a discussão acerca da utilidade de simulações de modalidade-específica para a compreensão da linguagem, as duas questões supramencionadas foram investigadas empiricamente através de cinco experiências. As Experiências 1 e 2 examinaram a influência da condição emocional (positiva, controlo ou neutra, negativa) nas medidas “online” (tempo de leitura, clareza das imagens, facilidade de apreensão e sentimento de presença) e “offline (questões textuais e inferenciais) de compreensão de discurso. Os participantes cujas atitudes faciais foram manipuladas no sentido de ficarem congruentes com a valência positiva do texto (condição compatível “caneta nos dentes”) geralmente revelaram tempos de leituras mais rápidos e maior apreensão do que leram relativamente aos participantes cujas posturas faciais foram incongruentes (condição incompatível “caneta nos lábios”) ou neutras (sem manipulação). As restantes medidas não revelaram um efeito da condição emocional. Os resultados obtidos são consistentes com estudos anteriores que utilizaram as frases (e.g., Havas et al., 2007) e suportam as teorias de cognição incorporada nas quais os símbolos abstratos são apoiados em sistemas sensório-motores (Barsalou, 1999a; Glenberg, 1997; Zwaan, 2004). Provavelmente mais importante, os resultados obtidos indicam que uma condição emocional compatível parece afetar a compreensão “online” não só ao nível da palavra e da frase, mas também ao nível do discurso.

Enquanto que as Experiências 2 e 3 avaliaram se as simulações de modalidade-específica permitem apreender informação explícita conotada à linguagem, a Experiência 3 avaliou se as simulações de modalidade-específica permitem apreender informação implícita suplementar às palavras mencionadas no texto. Os participantes leram narrativas com descrições de cenas que implicitamente sugeriam uma determinada posição espacial de uma pessoa ou de uma entidade, enquanto o seu corpo estava virado 90 graus para a direita (condição compatível), 90 graus para a esquerda (condição incompatível) ou numa condição normal sem manipulação corporal (condição neutra). A compreensão dos participantes foi avaliada através de medidas “online” (tempos de leitura, clareza mental das imagens, clareza mental de imagens específicas e presença espacial) e “offline” (sequenciamento de tarefas). Os resultados obtidos revelam que os participantes que leram o texto na condição compatível reportaram um maior nível de clareza mental de imagens, mas apenas no que diz respeito às passagens que descreviam movimentos envolvendo duas pessoas situadas à esquerda. As restantes medidas não revelaram um efeito de congruência entre a direção corporal e o processamento do discurso. Assim, pode ser concluído que mesmo as caraterísticas implícitas das simulações, tais como a dimensão espacial ou localização estão, pelo menos, algo envolvidas no processamento de amplos segmentos da linguagem tais como o discurso.

Por ultimo, as Experiências 4 e 5 foram realizadas para demonstrar que a participação em ações reais (exercício numa bicicleta fixa) ou meramente a preparação do sistema motor para uma ação (leitura do texto com uma perna em avanço) afeta o modo como os indivíduos compreendem um discurso com descrições de movimentos metafóricos. Os participantes leram um texto com descrições de movimentos metafóricos progressivos (e.g., perseguir um futuro melhor) enquanto os seus corpos estavam preparados (condição de facilitação) ou não (controlo) para o processamento de informação congruente com ação. A compreensão do discurso pelos participantes foi avaliada através de medidas “online” (tempos de leitura) e “offline” (precisão das respostas, tempo de reconhecimento de palavras do texto, tempo de avaliação da veracidade/falsidade de frases). Foi concluído que a simulação de ação tem maior efeito na compreensão “offline” implícita do que na “offline” explícita e que a compreensão “online” não parece ser consideravelmente afetada. Os resultados obtidos são consistentes com a teoria LASS (Barsalou et al., 2008), a qual prevê que a simulação afeta mais o processamento de informação baseado na dedução e interpretação e, num menor nível, o processamento superficial baseado na informação explicitamente fornecida no texto. Estas conclusões permitem avançar para além das Experiências 1 a 3 ao demonstrar que as simulações de modalidade-específica estão envolvidas igualmente na compreensão de discursos que descrevem ações metafóricas as quais são fisicamente impossíveis de desempenhar.

Em resumo, os resultados apresentados suportam a cognição incorporada, sugerindo que as condições sensório-motoras e afetivas estão implicadas, ao menos parcialmente, no processamento do discurso “online” e “offline”. É manifesto que as experiências descritas nesta tese não fornecem evidências de que não existem

representações amodais ativadas durante o processamento linguístico, mas demonstram que o apoio sensório-motor é necessário para a compreensão de segmentos amplos da linguagem como é o discurso.

Palavras-chave: Cognição incorporada, compreensão da linguagem, simulação sensório-motora, processamento “online”, processamento “offline”

Abstract

Theories of embodied cognition argue that language processing arises not from amodal symbols that redescribe sensorimotor and affective experiences, but from partial simulations (reenactments) of modality-specific states. Recent findings on processing of words and sentences support such a stance emphasizing that the role of the body in the domain of language comprehension should not be overlooked or dismissed. The present research was conducted to extend prior work in two important ways. First, the role of simulation was tested with connected discourse rather than words or sentences presented in isolation. Second, both "online" and "offline" measures of discourse comprehension were taken. In Experiments 1 and 2 participants' facial postures were manipulated to show that preparing the body for processing of emotion-congruent information improves discourse comprehension. In Experiment 3 the direction of body posture was manipulated to show that implicit properties of simulations, such as spatial dimension or location, are at least somewhat involved in processing of large language segments such as discourse. Finally, in Experiments 4 and 5 participants' body movement and body posture were manipulated to show that even understanding of language describing metaphorical actions physically impossible to perform involves constructing a sensorimotor simulation of the described event. The major result was that compatibility between embodiment and language strongly modulated performance effectiveness in experiments on simulation of emotion and metaphorical action. The effect of simulation on comprehension of discourse implying spatial dimension was fragile. These findings support an embodied simulation account of cognition suggesting that sensorimotor and affective states are at least partially implicated in "online" and "offline" discourse comprehension.

Keywords: Embodied cogntion, language comprehension, sensory-motor simulation, "online" processing, "offline" processing

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CHAPTER 1

Introduction

Abstract

This chapter provides a rationale for Ph.D. research. It establishes the importance of the present research within the current knowledge in the domain of embodied cognition and language comprehension and defines a problem under investigation. Likewise, this part explains the theoretical background, hypotheses to be tested, limitations of the dissertation, and research methods. Finally, Chapter 1 culminates in an outline of thesis organization and definition of some key terms and concepts that are typically used together, sometimes (mistakenly) interchangeably and synonymously in the domain of embodied cognition.

1.1. Theoretical background

Consider the following new experimental findings about language comprehension:

1. The processing of language triggers activity in sensory and motor areas of the brain associated with sensory- and action-related experiences (e.g., Aziz-Zadeh, Wilson, Rizolatti, & Iacoboni, 2006; Boulenger, Roy, Paulignan, Déprez, Jeannerod, & Nazir, 2006; Buccino, Riggio, Melli, Binkofski, Gallese, & Rizzolatti, 2005; Goldberg, Perfetti, & Schneider, 2006; Hauk, Johnsrude, & Pulvermüller, 2004; Isenberg et al., 1999; Martin & Chao, 2001; Oliveri, Finocchiaro, Shapiro, Gangitano, Caramazza, & Pascual-Leone, 2004; Pulvermüller, 1999, 2002; Tettamanti et al., 2005).

2. Sentence comprehension is facilitated when the literal body movement is consistent with that implied by the sentence. Conversely, sentence comprehension is impaired when the literal body movement is not consistent with that implied by the sentence (e.g., Bergen & Wheeler, 2005; Borreggine & Kaschak, 2006; Glenberg & Kaschak, 2002; Kaschak & Borregine, 2008; Taylor & Zwaan, 2006; Taylor, Lev Ari & Zwaan, 2008; Zwaan, Taylor, & de Boer, 2010).

3. Comprehension of emotional sentences is induced when the suggested mood of the sentence is congruent with the concurrent mood of the comprehender. Conversely, comprehension of emotional sentences is impaired when the suggested mood of the sentence is incongruent with the concurrent mood of the comprehender (e.g., Havas, Glenberg, & Rinck, 2007; Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010). Moreover, comprehension of sentences describing emotionally laden events primes particular actions. More specifically, reading of angry sentences leads to faster movements away from the body and reading of sad sentences leads to faster movements towards the body (Mouliso, Glenberg, Havas, & Lindeman, 2007).

4. Perceptual information such as orientation, shape, motion, color, and visibility is implicated in processing of sentences (e.g., Stanfield & Zwaan, 2001; Zwaan, Stanfield, &Yaxley, 2002; Zwaan, Madden, Yaxley, & Aveyard, 2004; Yaxley & Zwaan, 2007; Richter & Zwaan, 2009).

Recent research on embodiment offers a framework for coherently integrating all these findings (Damasio, 1989, 1994; Glenberg, 1997; Lakoff & Johnson, 1999). The basic idea of embodied theories is that sensorimotor processing is important for language understanding. According to Barsalou (2008a), this idea is well-supported by the claim that if humans evolved from creatures whose bodily systems relied on perceptual, motoric, and emotional processing, then sensorimotor and introspective processes should be also involved in language processing. Therefore, embodied theories of cognition reject traditional amodal views that understanding of language comes from manipulation of abstract, arbitrary, amodal symbols which have no reference to modality-specific systems of perception, action, and introspection (see Collins & Loftus, 1975; Newell & Simon, 1976; Landauer & Dumais, 1997, for more details regarding amodal language processing). Instead, embodied theories suggest that (a) language comprehension is a process of simulation (reenactment) of events acquired during original experience of the world (Barsalou, 1999a), and the simulation relies on sensory, motor, and introspective states; (b) language comprehension is affected by the unique structure of human body (Glenberg & Robertson, 2000); and that (c) language comprehension is simulated in the context of possible actions, agents, background situations, and interoceptive sensations from the body (Barsalou, Niedenthal, Barbey, & Ruppert, 2003).

1.2. Research problem and objectives

Each of the empirical findings presented at the beginning of the previous section is consistent with the embodied account of cognition suggesting that language processing arises from partial simulations of original sensory, motor, and introspective states. However, two issues call for attention.

The first issue is that none of these studies tested whether embodied representations get activated on the level of comprehension higher than sentence. This is an important limitation of the above-mentioned investigations as it makes it difficult to predict whether embodiment effects in sentence comprehension fully generalize to larger language segments such as discourse. Thus, although empirical work on embodied sentence comprehension presents a compelling argument on the role of bodily feedback in general language comprehension, there is still a distinct possibility that modality-specific simulations might not affect language processing above the level of sentence, considering that discourse is not an arbitrary combination of individual sentences. To further develop the importance of this issue for the current literature, consider the three fundamental differences between the discourse level processing and other levels of language processing suggested by Graesser, Millis, and Zwaan (1997). The first argument posed by the researchers is that most of the oral and written communication in human life proceeds in the form of discourse rather than sentence (e.g., dialogue, letter, story, article, etc.). The second argument is that people rarely process sentences without supporting context from discourse. Finally, the third argument is that discourse comprehension is closely tied with other important higher-level cognitive processes such as memory, reasoning, problem solving, etc. Similar arguments supporting the importance of discourse-level studies for the area of language comprehension can be found in other equally fruitful contributions (e.g., Graesser, Singer, & Trabasso, 1994; Sparks & Rapp, 2010; Zwaan & Radvanksy, 1998; Zwaan & Rapp, 2006).

The second issue concerns the fact that most research on language processing has so far tested embodiment effects using “online” measures of comprehension (e.g., reading times, gaze durations) rather than “offline” measures of comprehension (e.g., response times at test, questionnaire). Clearly, in studies on lexical access or sentence processing it is very often impossible to capture such important aspects of “offline” comprehension as, for instance, recall, summarization, argumentation, or inferencing due to the small size of language segments. However, discourse research offers just such an opportunity. More specifically, discourse represents an extended expression of thought on a particular subject, and thus allows the comprehender to construct the meaning of the message throughout the text, form his attitude towards the events described in the text, and, as a result, build an immediate and long-term memory representation of the events from discourse. Furthermore, discourse captures situational information that is so central for an embodied account of language processing: experiences and events mirrored in the real world that include people perceiving background situations, performing goal-oriented actions, and emotionally reacting to certain types of information (see Graesser et al., 1997, for discussion). Finally, the most recent research revealed that details of sensorimotor simulations are retained over longer periods in sentence processing (Pecher, Dantzig, Zwaan, & Zeelenberg, 2009) and that embodied interventions help children answer inference questions and better remember parts of texts (Glenberg, 2011, for discussion; Glenberg, Goldberg, & Zhu, 2011), suggesting that there are good reasons to think that embodied representations, which are constructed “online”, may affect “offline” processing of discourse. In brief, discourse-level studies provide an experimenter with powerful tools of testing “online” and, most importantly, “offline” processing of the events from discourse, given that such studies investigate how individuals build meaningful mental representations from extended linguistic events (e.g., textbooks, novels, stories, dialogues, articles, conversations) that correspond to naturalistic communication (Sparks & Rapp, 2010).

In sum, the current state of affairs in discourse and cognitive psychology literatures demonstrates the necessity to test embodied effects on comprehension on larger language segments than word or sentence using both “online” and “offline” measures of language comprehension. Therefore, the primary two objectives of this Ph.D. research are (a) to provide evidence suggesting that embodied representations get activated during discourse processing and (b) investigate whether the details of sensorimotor and introspective simulations affect both “online” and “offline” discourse comprehension.

1.3. Scope and methods of research

The experiments presented in Chapters Three, Four, and Five of this thesis aim to investigate whether sensory-motor grounding affects “online” and “offline” discourse processing. To more succinctly address the role of embodied representations in comprehension of discourse, the research in this thesis will be limited to processing of written language only (specifically, reading comprehension). Doing so narrows the scope of investigation and allows comparing whether the results of the present research are consistent with the previous literature on embodied reading comprehension at the level of sentences.

It is important to note that the evidence for activation of embodied representations during language comprehension has been collected using various experimental procedures across literature. Louwerse and Jeuniaux (2008) reviewed such experimental procedures and concluded that in most embodied experiments the evidence for the role of sensory-motor grounding in language processing comes from either linguistic and nonlinguistic stimuli used in combination, such as judging sensibility of sentences following pictorial information or judging sensibility of sentences while responding in either toward or away direction (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Glenberg & Kaschak, 2002; Matlock & Richardson, 2004; Zwaan & Yaxley, 2003), or linguistic stimuli only, such as semantic judgments, sensibility ratings, and memory load (Borghi, 2004; Fincher-Kiefer, 2001; Spivey & Geng, 2001; Wu & Barsalou, 2004). The experiments presented in subsequent chapters of this Ph.D. thesis included both linguistic and non-linguistic stimuli and were designed to demonstrate the following embodied effect: a compatibility of embodiment and cognition facilitates discourse comprehension. More broadly, according to embodiment theory processing of language requires simulation of certain perceptual, action, and introspective states. Consequently, putting the body of the comprehender, for example, into a congruent happy state while he is reading a text describing pleasant events (e.g., about happy relationship) should help him faster understand the text, and thus facilitate comprehension. Similarly, putting the body of the comprehender into an incongruent sad state while he is reading a text describing pleasant events should impair his processing of text, considering that an incongruent sad state should interfere with understanding of discourse describing pleasant events. Thus, in each experiment of this research the body was shifted into such states (either prior to reading process or during the reading process) to test whether embodied representations get activated and, as a result, help better comprehension of discourse. The means of shifting the body into appropriate states differed across experiments, given that different body states were manipulated (e.g., emotional, action, etc.), and these means of manipulating the body will be discussed in more detail at the onset of each respective empirical chapter.

The methods of assessing discourse comprehension are quite diverse, given that reading comprehension is a covert process that cannot be directly observed. Across literature, it is possible to find the following standardized measures of reading comprehension used by experimental psychologists and linguists: collection of reading times for paragraphs as readers passively read the text, collection of reading times for individuals words or sentences (interrupted comprehension) in the text (Graesser et al., 1997; Pachella, 1974), recording gaze durations (Spivey & Geng, 2001), asking multiple-choice (Kehoe, 1995), open-ended (Carlisle & Rice, 2004) types of questions, and asking to identify sequence of events (Gambrell, Pfeiffer, & Wilson, 1985) in the story (see also Fletcher, 2006; Haberlandt, 1994, for complete reviews). Considering that the main objective of the present research was to study the effect of sensorimotor grounding on both “online” and “offline” language processing, multiple reading assessments were used.

1.3.1. Methods of assessing "online" discourse comprehension

Online reading comprehension was measured by collecting reading times as comprehenders were normally reading the text (experiments one to five) as well as by assessing the vividness of mental imagery (experiments one, two and three), spatial presence (experiments one, two, and three), and the ease of reading (experiments one and two). The decision to measure the degree of mental imagery and spatial presence was guided by previous research on ocolumotor mechanisms activated by imagery (Spivey & Geng, 2001; Spivey, Tyler, Richardson, &Young, 2000). For instance, Spivey and Geng (2001) showed that when individuals were reading short stories describing upward, downward, leftward, and rightward events their eyes "followed" the visuospatial description implied by the texts, suggesting that people imagined perceiving objects and performing actions in the described scene as if they were actually there in the middle of the situation. Finally, Barsalou (2008b) noted that mental imagery is an integral part of mechanisms that underlie simulation, but whereas mental imagery is usually a result of deliberate attempts to construct conscious mental representations in working memory (Kosslyn, 1980, 1994), modality-specific simulations usually get activated unconsciously and outside of working memory. In brief, the rationale for inclusion of these measures is as follows: if bodily states for perception, action, and introspection are involved in language comprehension, then simulating these bodily states should affect perception and imagery and, accordingly, discourse comprehension (see also Barsalou, Solomon, & Wu, 1999, for empirical evidence). Clearly, these measures (i.e., vividness of imagery, feeling of presence, and ease of reading) are not direct comprehension measures as they involve the participants' metacognitive judgments on their own comprehension processes after the proper comprehension task. At the same time, such measures might shed some light on unrevealed effects in "direct" measures (reading times) of "online" discourse comprehension, and thus are theoretically interesting.

1.3.2. Methods of assessing "offline" discourse comprehension

"Offline" explicit reading comprehension was measured by open-ended questions (experiments one and two), a sequencing task which refers to the process of putting narrative events in the chronological order in which they occurred (experiment three), and a recognition task which involved measuring accuracy and the amount of time it took participants to recognize certain words from the target text (experiments four and five).

Offline implicit comprehension was measured with a Likert Scale from 1 to 7 with 1 being “completely disagree” and 7 being “completely agree”, which required from participants to indicate their level of agreement (based on implicit guessing) on statements referring to events from the target text (experiments one and two). Finally, in Experiments Four and Five “offline” implicit comprehension was measured by assessing participants’ accuracy and the amount of time it took participants to judge sentences as correct or incorrect with respect to the content of the text.

An appropriate justification for why different methods of data collection were used in some experiments will be provided in the “Method” section of each empirical chapter.

1.4. Hypotheses

A strong embodiment stance suggests that language comprehension arises from simulating the situation by using bodily systems employed in control of perception, action, and introspection (Goldstone & Barsalou, 1998; Kaschak & Glenberg, 2000; Kiefer & Pulvermüller, 2011; Zwaan, 2004). Based on embodiment theory, two major hypotheses can be formulated with regard to the influence of modality-specific simulations on discourse comprehension. A first hypothesis is that shifting the body into a congruent state with language meaning (e.g., emotional, action, etc.) should facilitate “online” discourse comprehension. Conversely, shifting the body into an incongruent state with language meaning should interfere with (impair) “online” discourse comprehension. For instance, if we are reading a story about someone escaping from a police station after being arrested on suspicion of a serious offence, we should be faster to process discourse when our bodily systems are prepared (e.g., by previously engaging in body movements associated with movements implied by discourse) for processing of language describing actions rather than unprepared or prevented from action-congruent processing. A second hypothesis is that modality-specific simulations also play important roles in “offline” comprehension of discourse. More concretely, if “offline” discourse comprehension indeed requires simulations, then participants whose bodily systems are prepared for processing of language describing congruent movements should demonstrate better performance on “offline: comprehension measures (i.e., open-ended and inference questions, accuracy, response times) compared to participants whose bodily systems are not prepared for such processing.

1.5. Overview of thesis organization

To test the above-mentioned hypotheses, five experiments were conducted on the role of modality-specific simulations in discourse comprehension. The research overview section presented next will briefly describe each of these experiments. However, for the reasons of clarity and consistency, the overview will commence with a theoretical chapter that provides a background for this research and will end with the presentation of empirical chapters.

In Chapter 2 amodal and embodied accounts of language comprehension are reviewed in more detail and their basic assumptions are compared. Then, empirical findings (from research on processing of concrete and abstract language) in support of embodied view of cognition are discussed as well as strong and moderate embodied theories that fully or partially account for these findings. Finally, the arguments that argue largely in favor of embodiment stance are discussed. The chapter concludes in an outline of research questions that were investigated in the subsequent empirical chapters of the thesis.

In Chapter 3 the role of emotion simulation in “online” and “offline” discourse comprehension is investigated through manipulation of facial posture. In the first experiment participants read a text describing positive events while having a pen between their teeth (muscular activation of the smile being facilitated) or in a normal condition without a pen (muscular activation of the smile being possible, but not facilitated). In the second experiment participants read a text describing positive events while having a pen between their lips (muscular activation of the smile being prevented) or in a normal condition without a pen (muscular activation of the smile being possible, but not facilitated). Participants’ comprehension was assessed by collecting reading times, asking to indicate their ease of reading, vividness of imagery, spatial presence (measures of “online” comprehension), and respond to explicit and inference questions (measures of offline” comprehension of discourse).

In Chapter 4 the role of implied spatial dimension in “online” and “offline” processing of discourse is investigated through manipulation of sitting body posture. In a single experiment participants were recruited to read a text implying left movements and locations and randomly assigned to one of the three conditions: matching (participants read the text while their body was turned 90 degrees to the right with the left shoulder advanced to the computer), mismatching (participants read the text while their body was body turned 90 degrees to the left with the right shoulder advanced to the computer), and neutral (no manipulation), and their comprehension was assessed by collecting reading times and asking to fill in a posteriori questionnaire that included the following tasks: vividness of general mental imagery, vividness of mental imagery regarding specific events from the target text, spatial presence (“online” comprehension measures), and a sequencing comprehension task (“offline” comprehension measure).

In Chapter 5 the role of action simulation in comprehension of discourse describing metaphorical actions is investigated through manipulation of body action systems. In two experiments (similar yet distinct studies) participants read a text describing metaphorical forward movements while their bodily systems were either prepared (facilitation condition) or not prepared (control) for processing of action-congruent information. Discourse comprehension was assessed by collecting reading times and analyzing accuracy and response times at test (recognition task, judgment task).

In Chapter 6 a summary of data base is presented and the reported results across the different studies are compared. Then, the limitations of research are discussed. Finally, the paper concludes with an outlook on future investigations that could help resolve some of the fundamental issued that fuel much of the discussion in the “embodiment” literature.

1.6. Definition of key terms and concepts

De Vega, Glenberg, and Graesser (2008) have noted that the use of key terms associated with amodal and embodied accounts of language comprehension is somewhat arbitrary in the current literature. Acknowledging the importance of this issue, key definitions will be introduced at the outset of this Ph.D. thesis to avoid confusion and ambiguity in the use of the various terms in the present research.

1.6.1. Amodal cognition

As in Louwerse (2011), present research considers the term “amodal” as a synonym for such other related terms as “symbolic” and “linguistic”. The basic assumption of amodal (symbolic) linguistic type of processing is that human cognition is very similar to computerized processing of information, where major operations are performed by central processing unit that is encapsulated from the input and output subsystems. Put different, such an approach suggests that sensory and motor systems play peripheral roles in processing of language, given that their only function comes down to delivering of information to a central processing unit (i.e., brain) via sensory systems and executing commands of this unit via action systems. Thus, amodal theories of cognition propose that processing of language can be explained solely in terms of relations among amodal symbols, pointing to the conclusion that amodal symbols are autonomous symbolic representations (Landauer & Dumais 1997; Kintsch 1998).

1.6.2. Embodied cognition

Pezzulo, Barsalou, Cangelosi, Fischer, McRae, and Spivey (2011) have noted that many terms, such as “grounded” or “situated” are used interchangeably with the term “embodied” in the current literatures, and that such arbitrary use of the above-mentioned terms may produce the mistaken assumption that all research in the area of embodied cognition focuses exclusively on the role of actual bodily states in representation of knowledge (see also Wilson, 2002, for a discussion of different forms of embodiment). However, this assumption appears to be incorrect, given that there is now a great deal of evidence demonstrating that such accounts of embodied cognition as *situated action* and *simulation* are as important for language processing as actual bodily states (Barsalou, 2008b, for further discussion). To more succinctly address the use of the phrases “grounded cognition”, “embodiment”, and “situated cognition” in the various collections of literatures, in the remainder of this part major accounts and terms of embodied cognition will be outlined. For each of the accounts, relevant empirical research will be introduced as appropriate.

1.6.2.1. Grounded cognition

A central claim of theories of embodied cognition is that linguistic symbols (e.g., words) derive meaning, at least partially, from non-linguistic perceptual, action, and affective experiences. That is, symbols are meaningful only when they are grounded in non-linguistic experiences. An already classical demonstration of such claim is provided in Harnad's (1990) merry-go-around argument, where the author asks to imagine being in a foreign country (e.g., Ukraine) and trying to understand the meaning of the message on a sign (in Ukrainian language) with the help of a dictionary written solely in that language. As you do not speak the local language, you look up the first word on the sign, but the definition of the word in the dictionary is comprised of more words that you also do not understand. Clearly, no matter how many words in the definition you look up, you will never be able to at least guess the meaning of the message on the sign, given that words are grounded in other linguistic symbols, but not non-linguistic experiences. Furthermore, there are now many empirical demonstrations confirming that meaning cannot arise solely from relations amongst abstract amodal symbols. For example, in the experiment of Glenberg and Mehta (2008) participants were instructed to memorize different types of relations between objects and features. Importantly, the names of the relations were revealed to the participants, but not the name of the domain, the names of the objects, and the names of the features. The results revealed that participants could not induce the meaning of objects and features, providing support for the conclusion that linguistic symbols only become meaningful when they are mapped to embodied representations of experiences conveyed by such symbols.

Summing up, grounding refers to a methodological approach of studying human cognition, where the environment, situations, the body, and modality-specific simulations are regarded the most important representations in cognition (Barsalou, 2010). Whereas the term "embodiment" suggests that major cognitive representations are shaped by sensorimotor and introspective bodily states, the term "grounding" or "grounding cognition" reflects a wider assumption – cognition is grounded in multiple ways, including environment, social interaction, bodily states, situated action, and simulations (Barsalou, 2008b).

1.6.2.2. Embodiment and simulation

A major claim of embodiment theories is that all cognitive representations rely on the brain's modality-specific systems and on actual bodily states (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005, Barsalou, 2008b; Wilson, 2002). Earlier embodiment theories primarily focused on the role of actual bodily states, aimed to demonstrate that bodily states play casual roles in affecting cognitive states (e.g., Lakoff & Johnson, 1980; Piaget, 1972; Smith, 2005, Zajonc & Markus; 1984). For instance, consider some popular research in the area of social psychology that focused on the role of the body for cognition. Riskind and Gotay (1982) put participants into an upright or slumped posture and later (after resuming normal posture) asked to solve different puzzles. The results revealed that participants in the upright posture dedicated more time and effort to solve the puzzles than participants in the slumped posture. In another experiment, Cacioppo, Priester, and Bernston (1993) instructed participants to push downward on the table (avoidance behavior) or upward on the table (approach behavior) and later rate Chinese ideographs. The major finding was that participants who pushed upward on the table provided higher ratings for the ideographs than participants who pushed downward on the table. Clearly, these findings are clear and consistent: bodily states of the individuals had an impact on their affective cognitive states.

In recent years, however, most contemporary theories of embodiment directed their attention from the effect of actual bodily states on cognitive processing to the effect of modality-specific simulations on cognition. In a variety of literatures, simulation is defined as reenactment of perceptual, motor, and emotional states acquired during original experience with the world (Barsalou, 1999a, 2008b; Glenberg, 1997; Zwaan, 2004). More concretely, during original experience the brain captures sensory states underlying perception of the situation, motor states underlying action, and affective states underlying emotion, and integrates these states into memory. Later, upon experiencing a similar situation, the brain's modality specific systems activate these original experiences to simulate the situation. Thus, listening to someone say "I smile when I remember my brother cooking in the kitchen" requires the activation of perceptual information (kitchen), action information (cooking) and emotional information (smile) to simulate sensorimotor and affective states that are a prerequisite for a full understanding of the message.

To sum up, the use of the term embodiment in its literal sense is restrictive as it primarily refers to the role of actual bodily states and simulations in cognitive processing. At the same time, grounding may be regarded as a synonym for embodiment with respect to the following assumption: cognition is grounded (embodied) in sensorimotor and affective bodily states (Pezzulo et al., 2011).

1.6.2.3. Situated cognition

A related topic in the domain of embodied cognition is that knowledge is situated in the context of likely background situations (Barsalou, et al., 2008). For example, knowledge of cigarettes is context dependent (e.g., settings, actions, introspections, etc.). That is, information about cigarettes might be simulated in the context of your friend smiling while smoking in the morning or, alternatively, your mother being angry with a man smoking nearby. In other words, embodied representations are context-specific and can be modified over time. Glenberg and his associates suggested that such situational knowledge is essential in preparing agents for action and effective immersion of agents into the environment of the presentation (e.g., Glenberg & Robertson, 1999, 2000; Kaschak & Glenberg, 2000). For example, imagine the following situation. You cannot swim and you are in the boat that is sinking. You can see a shore ahead and understand that the boat will sink unless you bail out. So you begin to bail out the water furiously with your hands, but it does not help. You look around and suddenly an idea comes into your mind. You take off your boot and start bailing out the water with that. You notice as the edge of the boat raises about 15 inches above the water and you realize that you are saved. What is so remarkable about this story? The answer is that a protagonist saved his life with an object that is not used by others to bail out water in everyday life. However, this situation describes just what situatedness is all about – cognition coordinates effective action in the context of current background situations (Glenberg, 1997). Thus, a boot in this particular case is simulated in the context of bailing out water rather than walking, suggesting that knowledge is situated. The idea of situated action is all the more noteworthy as it presents a challenge for computational amodal accounts that face problems making similar predictions regarding novel situations (see Glenberg & Robertson, 2000, for empirical evidence). Thus, it can be concluded that the term “situated cognition” can be regarded as a synonym to embodied cognition and grounded cognition only when one is aware of its restrictive meaning.

To conclude, the terms “grounded cognition”, “embodied cognition”, and “situated cognition” assume that knowledge is not separate from modality-specific systems of perception, action, and emotion. Although grounded cognition represents a wider assumption relative to other terms, a wide range of literature uses the terms “amodal”, “symbolic”, and “linguistic” as antonyms for “grounded”, “embodied”, and “situated”, suggesting that many of the terms in the domain of amodal and embodied cognition are used metonymically (De Vega et al., 2008; Louwerse, 2011). While this use is justifiable when the reference is made to the role of simulations in language processing, one should be aware of the restrictive use of each of these terms when referring, for example, to the above-described studies from social psychology literatures (i.e., it would be incorrect to consider “situated” as a synonym to “embodied” when referring to studies addressing how actual bodily states affect cognitive states).

In this Ph.D. research the term “embodied” is used as a synonym for “grounded” or “situated”, but the explicit focus of the thesis is on how language comprehension is grounded in perceptual, action, and emotional bodily states rather than in other agents, such as environment or social interaction. Moreover, like most current accounts of embodied cognition (Barsalou, 1999a; Decety & Grezes, 2006), this research will focus on the roles of simulation (reenactment of perceptual, motor, and affective states) in language comprehension rather than on the role of actual bodily states. Finally, it is possible that Barsalou and associates (Barsalou, 2008b, 2010; Barsalou, Santos, Simmons, & Wilson, 2008) are right: grounding may one day become such a widely accepted assumption that there will be no need to specify what is meant by language as grounded, embodied, or simulated as empirical demonstrations in the domain of embodied cognition continue to grow. The current status of the literature on the subject, however, suggests that one should be aware of the restrictive usage of such key terms and provide a reader with clear guidelines of what each term denotes in a particular research project.

CHAPTER 2

An Embodied Language Comprehension: A Review of Empirical Findings and Theories

Abstract

Recent findings in psychology, psycholinguistics, and neuroscience present a challenge to current amodal theories by suggesting that cognitive states are not disembodied in language comprehension. To assess this claim, a brief discussion on how amodal theories explain language processing is provided. Accumulating behavioral evidence supporting an embodied view is then reviewed from research on processing of language describing concrete and abstract concepts. Finally, the extant embodied theories that support either a strong (Perceptual Symbol Theory, Indexical Hypothesis, Immersed Experiencer Framework, Action-based Language Theory) or a moderate embodied view (Language and Situated Simulation Theory, Symbol Interdependency Hypothesis) are discussed, as are the arguments supporting the importance of embodiment for comprehension, and the following conclusions are reached. The results of a growing body of empirical research suggest that modality-specific simulations are important for language comprehension, and therefore the role of embodiment in processing of language can hardly be viewed as peripheral. At the same time, a revision of embodied language theories shows that there is no common agreement among scientists as to whether one (i.e., either amodal or embodied) or multiple systems (i.e., embodied and amodal) represent knowledge as well as under what circumstances embodied and symbolic representations get activated. This suggests that the supporters of embodied view of cognition are still far from a general unified approach to language processing. The chapter concludes with an outline of five research questions that will be investigated in the empirical chapters of this thesis.

2.1. Introduction

An amodal system theory that emerged from the Cognitive Revolution in the 1950s remained dominant for over five decades in the area of language comprehension. According to this theory, processing of language is based on abstract, amodal symbols that are arbitrarily related to their referents. From this perspective, the mind is an abstract information processor and sensory-motor systems are not relevant to understanding of higher-level cognitive processes (Fodor, 1975; Newell & Simon, 1972; Pylyshyn, 1984). The idea that relations among symbols may lead to successful language processing was corroborated by several symbolic models describing how human memory is organized semantically and schematically (e.g., Bobrow & Norman, 1975; Charniak, 1978; Norman, 1975; Quillian, 1969; Rumelhart, 1975; Shank & Abelson, 1975) as well as computational implementations, such as Knowledge Representation Language (Bobrow & Winograd, 1977), CYC (Lenat & Guha, 1989), Hyperspace Analog to Language (Lund & Burgess, 1966), Topic Model (Griffiths & Steyvers, 2004), and Latent Semantic Analysis (LSA) of Landauer & Dumais (1997). Furthermore, the demonstrations of the most popular model, such as LSA, in picking out synonyms, measuring coherence of texts (Landauer & Dumais, 1997), and even scoring students' essays (Landauer, Laham, Rehder, & Schreiner, 1997) led some scholars to support the potential of this model to account for human meaning (e.g., Landauer, 2002; Louwerse & Ventura, 2005).

Nonetheless, about 10 years ago the dominance of amodal theory was challenged and ultimately declined by the appearance of a new embodied account of cognition. This new account is based on the idea that language processing should be viewed in the context of relationship between the mind and the body. Neuroscientific research provided substantial support for this idea by demonstrating that the same sensory-motor regions of the brain get activated when individuals process the words and their referents (e.g., Eskenazi, Grosjean, Humphreys, & Knoblich, 2009; Gallese, 2008; Kan, Barsalou, Solomon, Minor, & Thompson-Schill, 2003; Martin, 2001, 2007; Pulvermüller, 2008; Thompson-Schill, 2003). Similarly, research in cognitive psychology and cognitive linguistics showed that language comprehension arises at least partially from simulations of sensory, motor, and affective states (Borghi, Ferdinando, & Parasi, 2011; Foroni & Semin, 2009; Gibbs, 2006; Glenberg, 1997;

Kaschak & Borregine, 2008; Knoblich & Flach, 2001; Zwaan, 2004). Therefore, embodied theories of cognition rejected amodal views that symbols can become meaningful on the sole basis of other symbols and suggested instead that symbols need to be grounded to their referents in the environment.

In the past years research on embodied language comprehension has grown exponentially. In neuroscience, researchers found that comprehension of action words in patients diagnosed with Parkinson's disease (Boulenger, Mechtouff, Thobois, Brousolle, Jeannerod, & Nazir, 2008) and apraxia (Buxbaum & Saffran, 2002) was selectively impaired, suggesting that sensory-motor simulations can hardly be viewed as by-products of language processing. In cognitive psychology, researchers such as Borghi (2004), Bub and Masson (2010), de Vega (2008), Glenberg and Kaschak (2002), Pecher, Zeelenberg, and Barsalou (2003), and Zwaan and Taylor (2006), found that modality-specific simulations can affect various language tasks in psycholinguistic embodiment experiments. What is all the more noteworthy, many other researchers, including Barsalou and Wiemer-Hastings (2005), Boroditsky and Ramscar (2002), Casasanto and Lozano (2006), Langston (2002), Pecher and Boot (2011), Richardson, Spivey, Barsalou, and McRae (2003), Santiago, Lupiáñez, Pérez, and Funes (2007), and Sell and Kaschak (2011, 2012) showed that comprehension of certain abstract concepts and sentences requires the involvement of sensory-motor simulations to the same extent as comprehension of concrete concepts and sentences. Finally, evidence for embodied representations formed the origin of language models, including Perceptual Symbols Theory of Barsalou (1999a), Indexical Hypothesis of Glenberg and Robertson (1999, 2000), Immersed Experiencer Framework of Zwaan (2004), and Action-based Language Theory of Glenberg and Gallese (2012). In brief, recent years in science have been marked by accumulation of empirical and theoretical evidence to support a claim that bodily states and modality-specific simulations play important roles in processing of language.

The purpose of this chapter is to provide a systematic review of how sensory-motor and affective processes contribute to sentence and discourse comprehension as well as to assess the commonalities and differences among the various findings and theories that currently drive discussions in the field. The Section 2.2 of this chapter provides a discussion on how amodal theories explain language comprehension. The Sections 2.3 and 2.4 review empirical evidence on processing of language describing concrete and abstract concepts that is consistent with an embodied view. The Section 2.5 discusses and explicitly contrasts a variety of old and new theoretical approaches that support either a strong embodied view (approach acknowledging the contribution of simulation) or a moderate embodied view (mixed approach acknowledging the contribution of both language and simulation systems). Finally, the Section 2.6 presents five arguments that suggest an important role to sensory-motor grounding in comprehension.

One caveat is important. The goal of this chapter is not to be exhaustive. Clearly, an advanced review of the importance of sensorimotor and introspective states to language comprehension could comprise several chapters of material, including evidence from studies on word comprehension (Hauk, et al., 2004; Martin & Chao, 2001*;* Tucker & Ellis, 2004), conceptual processing (Barsalou, 2003; Borghi, 2004; Pecher, Zeelenberg, & Barsalou, 2003), syntactic analysis (Chambers, Tanenhaus, & Magnuson, 2004), phonological processing (Fadiga, Craighero, Buccino, & Rizzolatti, 2002), and spatial representations (Boroditsky & Ramscar, 2002; Matlock, Ramscar, & Boroditsky, 2005; Richardson et al. 2003). Thus, this review has the following limitations. First, it focuses on sentence and discourse processing rather than single-word processing. Second, it discusses mainly behavioral data, but not neuroscientific and kinematic evidence. Doing so appears reasonable taking into account that the primary goal of this Ph.D. is to investigate the role of sensorimotor grounding on extended language segments such as discourse using the methods of data collection (e.g., reading times, questionnaire) characteristic of behavioral studies.

2.2. Language comprehension in symbolic and embodied cognition

2.2.1. Assumptions of symbolic cognition and overview of theories

The historically prevalent symbolic model of cognition suggests that language comprehension is amodal because it functions separately from sense modalities (e.g., Newell, 1980; Pylyshyn, 1984). Under this account, comprehension arises from forming associative relations between networks of propositions, feature lists, or statistical vectors that identify objects in the world. For example, the fact that a pencil can be inside a pencil case could give rise to the proposition “inside a pencil case”, the fact that a pencil case can be on the desk could give rise to the proposition “on the desk”, and the fact that a desk can be in the classroom could give rise to the proposition “in the classroom”. Figure 2.1 further illustrates this assumption indicating that sensory and cognitive representations, rather than sharing a common system, instead represent two distinct systems that work differently (also see Barsalou, Simmons, Barbey, & Wilson, 2003, for further discussion). More broadly, while sensory-motor system is involved in conscious experience of the outside world, amodal symbol system transduces sensorimotor experience to the mind in the form of frozen representations of the world. Thus, each time we experience something or get into contact with someone, our brain transforms original bodily states into a meaningful schema of amodal symbols that refer to these states. In brief, comprehension is achieved via redescription.

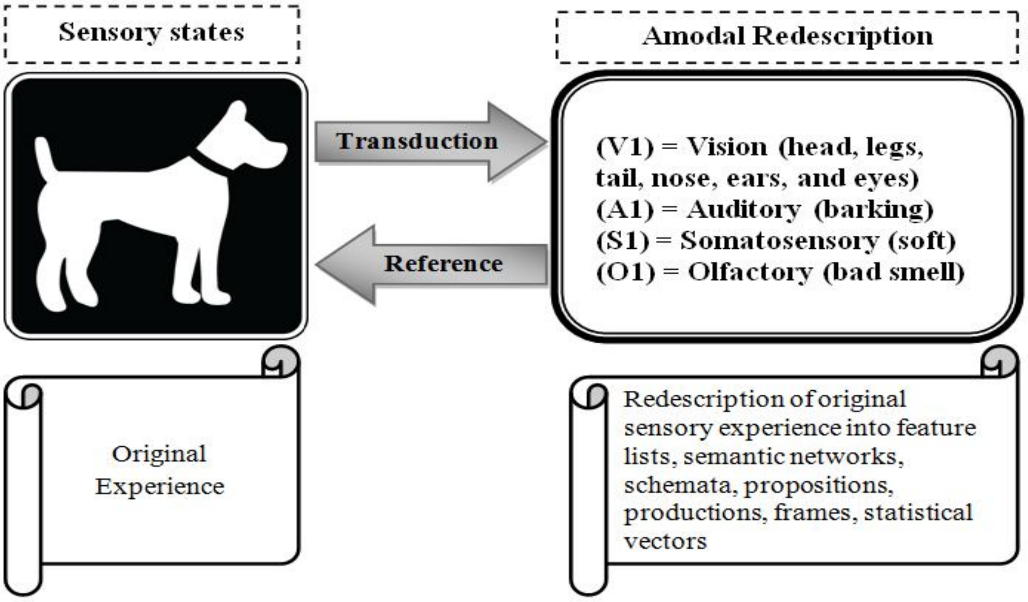

Figure 2.1. Language comprehension via an amodal symbols system.

Clearly, by adopting such an approach to language comprehension, it seems fairly easy to grasp the idea how the words are processed. But this really just begs the question: how to define linguistic units in the context of larger language segments such as sentence or text? To advance on this question, let’s look into the inner structure of the most common propositional type of symbolic representations by adopting the framework of Graesser, Gernsbacher, and Goldman (1997) who in much of their work review this structure (see Kintsch, 1974; 1998, for a more detailed description and explanation of representation of meaning via propositions in memory). In particular, the researchers note that a proposition is a theoretical unit that consists of a predicate (e.g., verb, adjective) and one or few arguments (e.g., nouns, embedded propositions) with each argument having a particular functional role (e.g., agent, patient, object, location). Propositions may refer to a state, an event, or an action.

To illustrate how meaning is extracted from the propositional representation, let's consider building a propositional segmentation for the sentence "Christopher found a fluffy puppy on the street and brought it home to feed". A propositional segmentation for the given sentence is presented in Table 2.1. First, the sentence has six propositions. Second, the predicates in these propositions are verbs (found, brought, feed), an adjective (fluffy), and connectives (to, and). Third, the arguments include a patient (puppy), an agent (Christopher), and embedded propositions (propositions 3 and 4 are embedded in proposition 5; propositions 1 and 3 are embedded in proposition 6). Finally, the arguments have the following roles: agent, patient, and location. Thus, a meaning for the given sentence is extracted from a predicate that denotes the nature of relation between the arguments in the given propositional structure.

Table 2.1

Propositional Representation for the Sentence "Christopher found a fluffy puppy on the street and brought it home to feed"

PROPOSITION 1	found (AGENT = Christopher, PATIENT = puppy; LOCATION = on the street)
PROPOSITION 2	fluffy (PATIENT = puppy)
PROPOSITION 3	brought (Agent = Christopher; PATIENT = puppy; LOCATION = home)
PROPOSITION 4	feed (PATIENT = puppy)
PROPOSITION 5	[in order] to (PROPOSITIONS 4 and 5)
PROPOSITION 6	and (PROPOSITIONS 1 and 3)

Whereas theories of propositional representation were formulated to suggest how language becomes meaningful via propositional framework, other symbolic theories were formulated to demonstrate how human memory is organized semantically and schematically and how such an organization affects processing of language. As an example of one of such models that focused on semantic processing, it is worth mentioning Quillian's theory (1962, 1967, 1969) of semantic memory search and semantic preparation. According to this model, a meaning of a concept is derived from a cofiguration of pointers to other words in the memory. To explain why a configuration of pointers represents meaning, Quillian uses an example of a machine. In particular, the researcher notes that when asked to tell all they know about machines, humans would first generate the most important properties (e.g., as machines are man-made, machines have moving parts, etc.), but then would describe the less important ones or almost irrelevant (a printer is a type of machine, quality of print depends upon the type of paper used in printing, etc.), suggesting that the amount of information that can be generated for any concept is unlimeted and that the information about different concepts is structured hierarchically. Figure 2.2. illustrates the structure of such semantic memory. For instance, a stored information from a sentence, "Compared to other animal groups, mammals such as dolphins have blowholes" has two pointers to category names "mammals" and "animals" and a pointer to such property as "have blowholes". In brief, such an organization suggests that detailed information about "dolphins" is not stored only with the memory node for each separate kind of mammal, but is instead stored with both the memory node for the separate kind of mammal and a higher-level category (e.g., mammal, animal). That is, the information stored in memory will not represent a concept such as "dolphin" listing all possible properties, but rather listing those properties that best describe only dolphins (e.g., has blowholes, loves humans, etc.).

The theory of semantic processing was tested empirically by Collins and Quillian (1969) who made a hypothesis that if information about concepts is dispersed along the network structered hierarchically, then participants would take more time to retrieve information from statements that describe properties dispersed along various levels (i.e., dolphin→mammal→animal) rather than from the same level (i.e., properties of dolphins only). Thus, the researchers expected that participants would retrieve information from a statement "Dolphins have blowholes" faster than from a statement "Dolphins can swim" as they do not need to move along the various levels to build a meaningful representation of a concept. To test this hypothesis, response times were collected as participants were judging if the statements such as "Canary is a canary", "Canary is a bird", and "Canary is an animal" were true. Remarkably, the reported results confirmed that participants took more time to judge if a sentence was true if information contained in the statement was dispersed along various levels of configuration. The graphical representation of the data is presented in Figure 2.3.

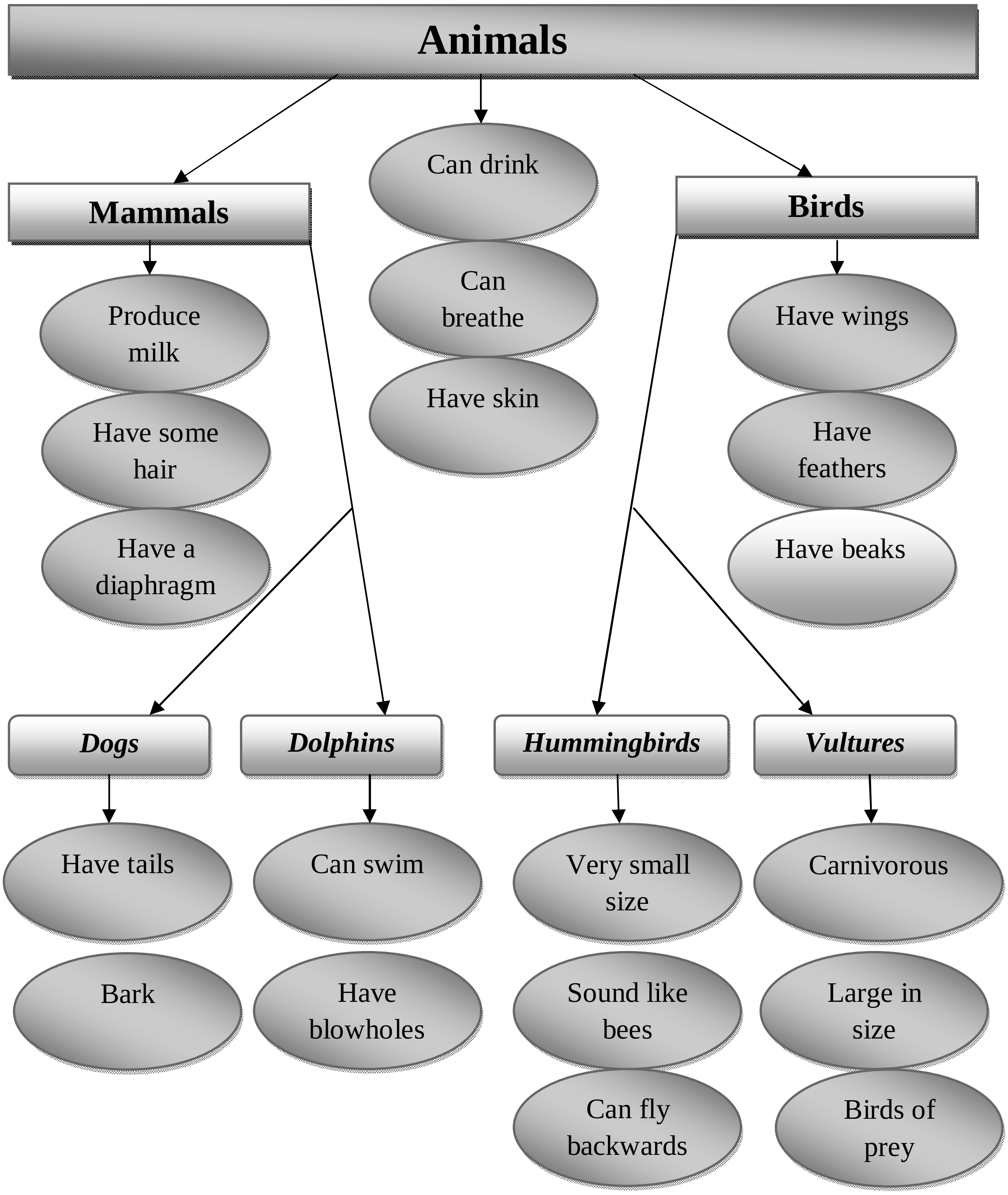

Figure 2.2. A schematic representation of how concepts are stored in memory according to semantic processing theory

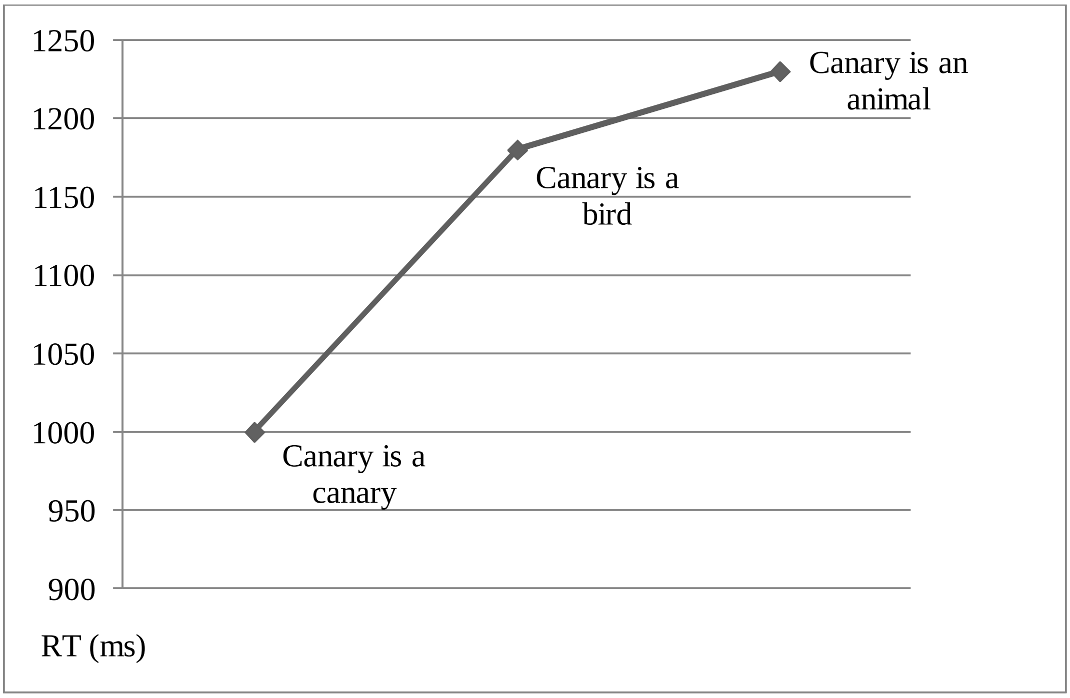

Figure 2.3. Average reaction times for different types of sentences in a study "Retrieval Time from Semantic Memory" by A. M. Collins and M. R. Quillian, 1969, *Journal of Verbal Learning and Verbal Behavior*, *8*.

There is a great body of other related research on problems concerned with semantic and structural organization of memory and aspects of language processing. Although this research differs on a number of important issues, it reveals a substantial convergence of opinion on essential aspects of cognitive processing (i.e., knowledge is amodal and represented in a network of interrelations). Consider, for instance, Rumelhart & Ortony's (1977) schemata account of knowledge representation. According to this theory, concepts are represented in human memory via schematas – network of interrelations between constituencies of a concept. The authors of the model compare internal structure of the schema to the script of the play. Just as in the play each actor is assigned his particular role and possesses certain characteristics (age, sex, appearance, etc.), so schematas have variables (characteristics) that may be shaped by the environment, social norms, contextual and situational factors. For instance, a schema for "CONGRATULATE" could have three variables: a guest, a present, and a receiver. That is, human interaction in the social world suggests that "congratulate" is associated with someone giving a present to someone else. In brief, schematas encode the possible network of interrelations about the concept in question. A similar organization of knowledge was offered by Minsky (1975) who suggested that information in memory is stored in frames – data structures to represent stereotyped information. Just like schematas, frames have variables that associate with the environment or situation. For instance, a frame for "CONGRATULATION" can be associated with a present, a cake, balloons, friends, family, etc. Importantly, frames can be adapted to fit reality by changing details as necessary even though most basic characteristics would usually remain constant. Similar arguments about cognitive processing can be found in the works of Bobrow and Norman (1975), Norman (1975), Charniak (1978), Rumelhart (1975), Shank and Abelson (1975), and Smith, Shoben, and Rips (1974).

The above-mentioned theories describing the organization of information in memory led to implementation of various computational models of language processing. Frame Representation Language (Bobrow & Winograd, 1977), Knowledge Representation Language (Fikes & Kehler, 1985), and CYC (Lenat & Guha, 1989) are only some of the examples of such models. In recent years three computational models heat the debate in the areas of psychology, psycholinguistics, and computational linguistics: Hyperspace Analogue to Language (Lund & Burgess, 1996), Latent Semantic Analysis (Landauer & Dumais, 1997), and Topics Model (Griffiths & Steyvers, 2004). Because of space limitations, only first two models shall be described in more detail.

In HAL (Hyperspace Analog to Language) model word meaning is derived from the frequency of word co-occurrences. The corpus that is used in the model consists of approximately 300 million words from Usenet newsgroups to produce a matrix of 70.000 rows and columns. The idea of word-by-word matrix is to determine the strength of association between the words in the rows and in the columns. The rows represent the values for words which precede the word corresponding to the row label and columns represent the values for words that follow the word corresponding to the column label. The total co-occurrence vector is calculated both from rows and columns. Thus, in a large corpus one could expect to meet the words with the similar meaning, such as *computer*, *laptop*, *netbook*, or *Portugal*, *Azores*, *Madeira*, to appear close to each other. To calculate word co-occurrences, one has to count the number of times the word "X" occurs closely to the word "Y". If the word "X" is adjacent to the word "Y", it receives a maximum value of 10. If the word "X" is separated from the word "Y" by one word, it receives the value of 9. If separated by 2 words – the value of 8 and so on. Having assigned values to all the words, the co-occurrence of words can be checked by looking at the rows. Words that tend to co-occur would usually have very similar values in the rows (see Table 2.2).

Table 2.2

Co-occurrence Square Matrix in a Window of Six Words with the Maximum Co-occurrence Value of 5.

	computer	laptop	netbook	Portugal	Azores	Madeira
computer	0	3	4	0	0	0
laptop	3	0	5	0	0	0
netbook	4	5	0	0	0	0
Portugal	0	0	0	0	4	3
Azores	0	0	0	4	0	5
Madeira	0	0	0	3	5	0

Note: The values in the table merely serve to demonstrate how a typical co-occurrence matrix would look like if words in the corpus occurred closely. These values were not calculated using HAL’s model.

Latent Semantic Analysis (LSA) is another computational model that is most widely used in the research these days. It was described in various publications and the explanation of the method that follows uses Landauer, Foltz, and Laham (1998) as the main reference. The major idea of LSA is to find out related terms and phrases in the context of one or more documents. The first step in the analysis is to represent a text as a matrix, where rows refer to target words and columns – to a text passage in which such words are used. Each cell contains the frequency of word co-occurrence in the given context. Next, each cell frequency is transformed (a computation from matrix algebra is too complicated to account with simple explanation, and thus is not included) to determine the word’s importance within the context of a given passage and discourse in general. The second step in LSA is to apply a singular value decomposition (SVD), which is similar in effect to factor analysis, to the matrix. The result of such decomposition is a creation of three matrices that capture associations between words and phrases. To cut a long story short, all major equations in LSA rely on the context in which any target word is used.

The capabilities of the model were evaluated in several different tests. One of the most popular types of tests where the model was assessed is a TOEFL (Test of English as a Foreign Language) standard vocabulary test (Landauer & Dumais, 1997). The TOEFL vocabulary test requires from the test taker to choose one of four alternative answers (single words) that is most similar in meaning to the target test word. To perform this test, LSA was trained by running SVD analysis on 4.6 million words of text form Grolier's Academic American Encyclopedia (Grolier Incorporated, 1998) with 30.473 articles (equivalent to the amount of read material by a pupil of eighth grade). The major result was that a model got 64.4 % on a vocabulary test comparing to the 64.5 % score of an average non-native English speaker who takes the Test of English as a Foreign Language.

In fact, the impressive demonstrations of LSA in picking out synonyms, measuring coherence of texts (Landauer & Dumais, 1997), or scoring students' essays (Landauer et al., 1997) led some scholars to support LSA's potential to account for human meaning. However, as it will be discussed in more detail later, LSA was criticized on its inability to define the meaning of implicit messages where meaning goes considerably beyond words mentioned in the text. Its mechanism of comprehension is downplayed by the fact that LSA is a disembodied machine that defines meaning of abstract symbols solely in terms of relations between other undefined abstract symbols (Glenberg & Robertson, 2000).

In sum, the following general conclusions about symbolic view of cognition can be made. First, knowledge is generated via amodal symbols (e.g., statistical vectors, network of propositions, feature lists, etc.). Second, knowledge is not linked to sensory, motor, and introspective systems of human body. Third, knowledge is a redescription rather than a simulation (reactivation) of an originally experienced event. These assumptions about the human mind made many scientists compare traditional amodal approach to the work of a contractor who puts together bricks to build structures. Like in construction, in amodal language comprehension initial experiences with the world are redescribed into mental bricks commonly referred to as propositions. As a result, language processing proceeds by adding up these bricks together (Zwaan and Madden, 2005).

2.2.2. Symbolic cognition and discourse models

The idea of amodal redescription in human mind was widely exploited among the researchers who worked on a medium known as discourse. These researchers, whose major work aligned with traditional amodal theory of knowledge representation, suggested some new challenging and innovative insights into the study of language. First, they started looking into the ways people understand large language segments such as, for example, texts (in written communication) and conversations (in oral communication). Second, they started questioning what exactly happens in the brain when comprehenders combine elements of such large language segments. Third, they initiated a discussion about the segregation of comprehension into various levels. Finally, and most importantly, they set a challenge to investigate how propositions are combined in the brain to achieve the coherence of language stream. In the remainder of this section, influential models of traditional discourse comprehension shall be described that have come to lay the foundations for past and current debates in the field of language processing.

One of the most influential models of discourse processing was put forward by Kintsch and van Dijk (1978; van Dijk & Kintsch, 1983) who suggested that discourse processing proceeds via three distinct levels. The first level, which is relatively short-lived, is called surface representation, and it consists of text’s literal wording. At this level readers remember the form rather than the content of the material. The second level, textbase or propositional, consists of deriving meaning from propositions or network of prepositions sharing a common feature (e.g., pencil – in the pencil case – on the table – in class). At this level readers build mental representations of meaning that is explicitly expressed in the text. The third level, situational, consists of combining explicit information of the text with reader’s general knowledge held in long-term memory. At this level readers make inferences about information not literally given in the text.

In several prominent works it was shown that the three levels of comprehension (surface, textbase, and situational) are indeed present in mental representation of discourse (e.g., Fletcher and Chrysler, 1990; Kintsch, Welsch, Schmalhofer, & Zimny, 1990). At the same time, the model of Kintsch and van Dijk (1978; van Dijk & Kintsch, 1983) was criticized on the grounds of its inability to show the integration of textbase representation into situational representation. As a result, research efforts were directed at developing the models of discourse comprehension that could help understand how the readers construct situational representations. The construction theory (Graesser et al., 1994), the construction-integration model (Kintsch, 1998, 1990), the structure building framework (Gernsbacher, 1990, 1997), and the memory focus model (Sanford and Garrod, 1994) are only some of the models that attempted to explain how knowledge is situated in processing of discourse.

It is beyond the scope of this research to provide a thorough review of each of the models. However, the objective is set to show the underlying principle and speak about the mechanisms that constitute discourse comprehension according to these models. For instance, in a revised model, Kintsch (1998) attempted to solve the problem of "situational representation" by proposing that comprehension is achieved via the two-step process: acontextual construction and context-guided integration. During the first step of construction, explicit meanings of the words are formulated through combinations of propositions without regards to the discourse context. The construction of propositions is formed via an unstable network of associations, which occurs in cycles corresponding to phrases or sentences. With each cycle to follow, a network of associations is constructed by combining information from the current and previous cycles. Once the association process is finished and its results are stored in a long-term memory, discourse context comes into play and integration process takes place. Finally, meaning arises from choosing between those elements that are appropriate for the discourse context, as a result of which a stable network of associations is formed. Thus, comprehension is achieved by (a) constructing propositions; (b) forming associations; and (c) choosing between meaningful and meaningless associations.

A similar two-step process to account for situational representation can be found in other models. For instance, according to Memory Focus Model of Sanford and Garrod (1981, 1994) comprehension is also realized via two steps. During the first phase memory stores information expressed explicitly in the text and during the second phase memory draws inferences from the previously stored information by assigning to it general knowledge of the described event. As a result of these processes, an implicit framework is constructed and the brain no longer experiences problems in knowing which propositions to build. In brief, traditional discourse theories clearly show that comprehension proceeds in an incremental fashion, whereby the ultimate goal of discourse processing is construction of a situation model. Such a model is constructed by combining the network of propositional associations with the discourse context.

Traditional theories, though widely used and recognized by scientific community, have recently undergone a wave of criticism on the following grounds. First, no answer has so far been provided how relevant contextual information is extracted from discourse content. Second, it is still not very clear how such contextual information is combined with a propositional network established at the textbase level. More basically, if traditional discourse theories share the view that language has evolved in the service of perception and action (e.g., Kintsch, 2008), then they still fail to disprove the possibility that knowledge is represented in the form of corresponding sensorimotor simulations rather than amodal symbols. Finally, as it will be discussed shortly, empirical findings challenge the assumptions and mechanisms regarding language comprehension offered by traditional discourse models by suggesting that language processing is directly grounded in systems of perception, action, and introspection.

2.2.3. Criticisms of symbolic cognition and assumptions of embodied cognition

Nonetheless, although many of the propositions are indeed direct representations of corresponding ideas (e.g., “bucket” is “bucket”) and most of the meaning representations come from a semantic network of relations between the target word and other words in the sentence (e.g., buckets are associated with water, mops, etc.), the amodal view is still not viewed by many scientists as a full-fledged theory of language comprehension. There are at least three reasons for this. First, a list of propositions (features) cannot always account for the correct combination of relations in language (Barsalou, 1999a). For example, “a painting *on* the wall” is not the same as “a painting *on* the floor”. Second, a semantic network cannot derive meaning from sentences in which words are not related semantically (Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999). For example, the sentence "My thoughts are not in this room right now" does not mean that thoughts are able to travel. Third, words differ in meaning depending on the goals of people (Glenberg & Robertson, 2000). For example, the meaning of the word "table" would differ depending on whether you plan to use it for studying or changing a light bulb. All of the reasons mentioned so far illustrate the interpretation problems associated with an amodal theory of language processing. These difficulties in interpretation are examples of what is known as the symbol grounding problem (Searle, 1980). The major idea behind this problem is that because meanings are not grounded in sensorimotor systems, comprehension is tantamount to seeking definition for the foreign word in a language that is unfamiliar to you (Harnad, 1990).

Recently amodal architecture was widely criticized on other grounds. First, it was noted that no empirical evidence exists to support the claim that comprehension proceeds via redescription process or that amodal symbols are present in the brain (Niedenthal, et al., 2005). Second, increasing evidence in support of simulation account of knowledge representation was demonstrated that cast serious doubt on previous research and theory suggesting that knowledge is entirely amodal (e.g., Barsalou, 2008a; Boroditsky & Prinz, 2008; Glenberg & Kaschak, 2003). As a result of these criticisms, an alternative account of cognition was proposed that gave rise to the idea of knowledge as "embodied" or grounded in bodily states and brain's modality-specific systems. The major claim of this approach is that because people live in a physical world, comprehension cannot be entirely symbolic. Instead it should rely on sensory, motor, and affective states (e.g., Barsalou, 2002; Damasio, 1989; Gallese, 2003; Lakoff, 1987). It is suggested that such view of language comprehension is natural as it not only allows to account for primary meanings of concepts, but as well to simulate the various meanings of these concepts in the context of relevant actions, events, settings, and introspections (Barsalou, et al., 2008). Thus, under this account, understanding a sentence "I stroke a cat with a wide smile on the face" will require the retrieval of perceptual information to simulate entities described in the sentence (cat), the retrieval of motoric information to simulate the "stroking" action, and the retrieval of emotional "happy" state (Figure 2.4).

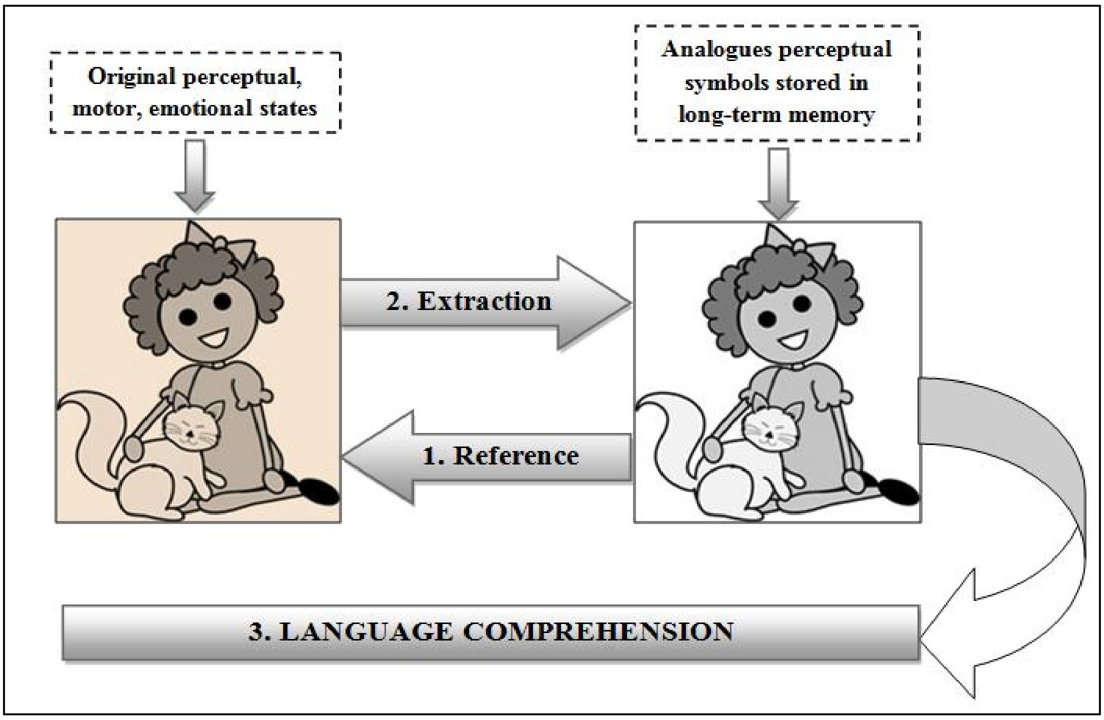

Figure 2.4. Comprehension of the sentence "I stroke a cat with a wide smile on the face" according to an embodied view of cognition. [Photo credit: http://www.clipartclipart.com].

An embodied approach to language comprehension is supported by a strong body of empirical evidence. In subsequent part such evidence is reviewed, suggesting that modality-specific simulations are necessary for language processing.

2.3. A review of evidence on processing of language describing concrete concepts

The purpose of the following section is to review extant empirical research demonstrating the impact of embodied simulations on processing of concrete language. Given the abundance of evidence, the purpose in this literature review is not to be comprehensive but, instead, to establish the common principles that are found in the various findings. Doing so will help to identify how researchers discuss the importance of embodied factor in concrete language processing with so many findings to choose from.

2.3.1. Perceptual simulation

The idea that perceptual knowledge is implicated in cognition is not new. Previous studies on spatial representations (e.g., Black, Turner, & Bower, 1979; Bower & Morrow, 1990; Gernsbacher, Varner, & Faust, 1990; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986) suggested that visual and verbal components of comprehension are interconnected. Similarly, neuroscientific evidence (e.g., Boulenger et al., 2006; Goldberg et al., 2006; Hauk et al., 2004; Martin, 2007; Oliveri et al., 2004) demonstrated that perception of objects that index auditory, gustatory, tactile, and visual knowledge triggers activity in sensory-motor areas of the brain. This section reviews six major lines of research which demonstrate that perceptual simulation is necessary for language processing.

2.3.1.1. The effects of implied perceptual features on immediate sentence comprehension

In this line of research, participants were presented with sentences describing objects or animals in various visuospatial configurations. After reading (listening) the sentence, participants were presented with a picture of the object or animal that the sentence described. The task consisted in judging whether the object (animal) was mentioned in the sentence. For example, Stanfield and Zwaan (2001) tested the hypothesis that people mentally represent the orientation of an object implied by the sentence. They asked participants to view a series of sentences (e.g., “John pounded the nail into the wall”; “John pounded the nail into the floor”), each followed by a picture in either vertical or horizontal orientation. During the experiment picture orientation either matched or mismatched the orientation implied by the sentence. The participants’ task was to indicate whether the object was mentioned in the sentence by pressing a key labeled “Yes” or a key labeled “No” on a computer. The major result was that participants were faster to respond to picture stimuli that matched orientation implied by the sentence rather than mismatched. In another experiment Zwaan, Stanfield, and Yaxley (2002) tested the prediction that people also mentally represent the shape of an object described in the sentence. Participants were instructed to read sentences that described animals or objects in a different location, implying a different shape (e.g., “The ranger saw the eagle in the sky”; “The ranger saw the eagle in its nest”). After each sentence, participants were presented with the picture of an animal or an object that varied in shape (e.g., eagle with outstretched wings; eagle with folded wings) and their task was to decide whether the picture represented a word implied by the sentence. The results demonstrated faster responses for picture stimuli that matched property of shape with the sentence rather than mismatched. A similar Match advantage was found in the related studies of Zwaan, Madden, Yaxley, and Aveyard (2004) on simulation of motion (e.g., “The shortstop hurled the softball at you”; “You hurled the softball at the shortstop”) and Yaxley and Zwaan (2007) on simulation of visibility (e.g., “Through the fogged goggles, the skier could hardly identify the moose”; “Through the clean goggles, the skier could easily identify the moose”). Finally, in the most recent studies Zwaan and Pecher (2012) replicated and Engelen, Bouwmeester, de Bruin, and Zwaan (2011) extended Stanfield and Zwaan’s (2001) and Zwaan et al.’s (2002) findings regarding simulation of orientation and shape. More concretely, in a study of Englelen et al. (2011) researchers asked participants (children of 7-13 years of age) to listen to (Experiment 1) or read a sentence (Experiment 2) describing an entity and then perform a picture verification task. The results indicated that responses were faster (in both experiments) when the shape or orientation of the depicted object matched the shape or orientation of an entity described in the sentence. What is all the more noteworthy, the same pattern of responding was observed both in children with high reading ability and children with low reading ability, suggesting that the effect of simulation is strong. Apparently, all these findings are consistent with the predictions derived from the embodiment claim: people mentally represent the perceptual features implied by a sentence. This in turn indicates that understanding a sentence suggesting a particular perceptual feature for an object calls on the same neural and bodily states involved in real perception of an object.

2.3.1.2. The effects of implied perceptual features on long-term sentence comprehension

Stanfield and Zwaan (2001) and Zwaan et al. (2002) in their experiments demonstrated that sentence comprehension proceeded better when the picture that immediately followed the sentence matched the orientation and shape of the object that was conveyed by the sentence. With an idea to demonstrate that details of sensorimotor simulations are retained over longer periods, Pecher et al. (2009) asked participants to first read the complete list of sentences and then perform speeded judgment tasks on the pictures that tested memory for the sentences by pressing a key "Z" with their left index finger for a no-response (does not correspond to the sentence) or a key "M" with their right index finger for a yes-response (corresponds to the sentence). Importantly, one group of participants engaged in a memory-decision-response task right after reading the sentences and the other group only in 45 minutes after sentence presentation. The results showed that recognition memory for pictures in both groups was better if the picture matched the implied shape or orientation of the object in an earlier presented sentence. The major contribution of this finding was that simulation affected sentence processing even when sentence reading and picture recognition were separated in time (45-min delay), suggesting that perceptual simulations affect both immediate and long-term comprehension processes.

2.3.1.3. The effects of spatial iconicity on language processing

Zwaan and Yaxley (2003) investigated whether spatial iconicity affects semantic-relatedness judgments. More concretely, in this research participants were presented with words pairs, such as *attic-basement*, in the middle of a computer screen with one word appearing below the other (e.g., basement above attic or attic above basement) and had to decide whether these pairs of words were semantically related. Importantly, positions of the words either matched or mismatched the corresponding positions of their referents in the real world (i.e., attic is generally situated above the basement in a house and basement – below the attic). It was found that response times were faster when the word pair matched the visuospatial configuration of the referents in the real world than when the word pair mismatched such configuration. Additionally, to ascertain that the effect was not due to the order in which the words were processed, the same pairs of words were presented horizontally. However, no significant effects were found. The researchers interpreted this finding in light of embodiment theory. That is, participants perceptually simulated the meaning of word pairs to make semantic judgments.

2.3.1.4. The effects of perspective on language processing

In recent years a great body of evidence has emerged to support a conclusion that situatedness of cognition plays important roles in conceptual processing. For instance, Borghi, Glenberg, and Kaschak (2004) demonstrated that in processing of sentences individuals not only simulate the objects or states described by the sentence, but as well the surrounding space. More precisely, it was reported that participants were faster to attribute an object (denoted by a noun) to a certain location when the noun that referred to an object was available in the participant's perspective implied by a preceding sentence. That is, participants were faster to verify a noun "sign" when it was preceded by a sentence "You are waiting outside a restaurant" than a sentence "You are eating in a restaurant". This finding suggests that cognition is situated and that in perception of the target event humans continue to pay attention to background situation that provides the context for such event. Put different, while thinking of a sign or processing information about a sign we do not only rely on perceptual simulation of sign as a physical object, but as well on the surrounding space, including perspective.

2.3.1.5. Specificity of the processing mechanisms required to construct simulations

In this line of research, the investigators explored the relationship between processing mechanisms required to construct a simulation and language comprehension. For instance, Kaschak et al. (2005) instructed participants to view dynamic black-and-white stimuli (in the direction towards or away from the person) and simultaneously listen to sentences that described motion in either the same or different direction as the motion of the stimuli (e.g., "The car approached you"; "The horse ran away from you"). The task consisted in pressing a key labeled "Y" if the sentence made sense, and a key labeled "N" if the sentence did not make sense. The major result was that responses were faster for sentences presented with a visual stimulus depicting motion in the opposite direction as compared to the action described in the sentence. A mismatch advantage was also found in a similar study of Kaschak, Zwaan, Aveyard, and Yaxley (2006) when participants read sentences that stressed auditory aspects (e.g., "The surfer heard the next wave crashing toward him"; "The victims screamed as the rising water swept them away down the river").

In particular, the task consisted in making sensibility judgments on the sentences (by pressing keys labeled “Y” or “N” on the keyboard) conveying motion toward, away, upward, and downward relative to the listener. The auditory stimuli were bands of white noise that created an impression of motion to the participants. The results of these two studies are particularly valuable in terms of identifying boundary conditions that specify how simulations are constructed. Kaschak and collaborators concluded that two factors weighed heavily in favor of a Match or Mismatch advantage: temporal overlap (timing of the stimulus and sentence to be processed) and integratability (the extent to which the stimuli can be integrated into the simulation). More broadly, the researchers suggested that when participants simultaneously view a visual stimulus and listen to a sentence (Kaschak et al., 2005), a Match advantage occurs when the sentence and the stimulus are integratible (e.g., when one sees an image of an eagle in the sky while reading and processing the sentence “I see an eagle in the sky”), and a Mismatch advantage occurs when the sentence and the stimulus are not easily integratible (e.g., when one sees an image of a black dot in the upper part of the computer screen while reading and processing the sentence “I see an eagle in the sky”). At the same time, when participants simultaneously view sentences that stress auditory aspects and listen to a stimulus (Kaschak et al., 2006), a Mismatch effect occurs due to competition for processing resources in the auditory perception system (i.e., perception of auditory stimulus requires the resources of perceptual auditory system, making them less available for a simulation of a sentence stressing auditory aspects). Finally, when a stimulus and a sentence are presented sequentially, a Match advantage arises under the condition that the percept and the sentence are integratible.

2.3.1.6. Interference between visuospatial memory load and comprehension.

In this line of research, Fincher-Kiefer (2001) and Fincher-Kiefer and D'Agostino *(*2004) instructed participants to read narratives in either high-imagery or low-imagery conditions by manipulating memory load. More broadly, participants read sentences about scenes while maintaining either interfering visual information or noninterfering verbal information in their working memory and later were asked to recall all memory load sentences. The major result was that the recall of described scenes was impaired when memory contained irrelevant visual information, but not when it contained neutral verbal information. This pattern of results was taken as a support to the claim that situation models generated from text comprehension include perceptual processing and simulations. These studies are important for psycholinguistic embodiment research as they are among the first to indicate that perceptual simulations may affect processing above the level of sentence (also see Spivey & Geng, 2001, for discussion of eye movements during processing of texts describing spatial scenes).

2.3.2. Action simulation

The importance of the motor system has been recurrently stressed in studies addressing the role of action for memory (Glenberg, 1997), categorization (Ross, 1996), cognition (Johnson, 1987), and evolution (Rizzolatti & Arbib, 1998). In recent times, however, research from psychology, neuroscience, and cognitive linguistics has also demonstrated the importance of the motor system for language comprehension (see Fischer & Zwaan, 2008; Gallese, 2007; Gibbs, 2006; Pulvermüller, 2002, for reviews). This part presents four major lines of research in which the case of action is presented.

2.3.2.1. The effects of congruency between motor action and the action described in the sentence on sentence comprehension

In this line of research, participants were asked to perform different motor actions while reading sentences to test whether compatibility between motor action and the action described in the sentence facilitates sentence processing. For example, Glenberg and Kaschak (2002) asked participants to view series of sensible sentences that either described transfer toward the reader (e.g., "Open the drawer") or away from reader (e.g., "Close the drawer") as well as series of nonsense sentences (e.g., "Boil the air") that did not imply any transfer. The task was to judge if sentences made sense by pressing one of the vertical keys on a three-button box that required a movement either toward or away from the body. The researchers found that responses were faster when the motion implied by the sentence matched the actual hand motion. This matching advantage was called the action sentence compatibility effect (ACE). The results of this study are clear and consistent: understanding the meaning of the sentence calls on experience with real motor action. The modulation of the motor system by sentence comprehension was further investigated in a study of Scorolli and Borghi (2009). Participants were presented with 24 pairs of nouns and verbs that described hand and mouth actions (e.g., to unwrap *vs.* to suck the sweet) and 24 pairs of nouns and verbs that described hand and foot actions (e.g., to throw *vs.* to kick the ball) and had to decide whether the combinations were sensible or not by saying “yes” loudly into a microphone or pressing a pedal. The results revealed that sentences implying mouth actions were processed significantly faster than sentences describing hand actions when participants were responding with the pedal. Similarly, sentences describing foot actions were processed faster when response was made with a pedal rather than a microphone. Apparently, this finding stands in stark contrast with amodal theories that claim language symbols become meaningful on the sole base of other language symbols. ACE effect was also reported in experiments of Borreggine, and Kaschak (2006), Taylor, Lev Ari, and Zwaan (2008), and Zwaan and Taylor (2006). For example, in the latter study participants read sentences implying rotation movement (e.g., “Because the music was too loud, he turned down the volume”) while actually rotating a knob. The direction in which the knob was rotated either matched or mismatched rotation movement described in the sentence. The results confirmed the matching effect between motor action and sentence meaning reported by Glenberg and Kaschak (2002). At the same time, the reported match advantage turned out to be quite specific: an activation of compatible motor responses was localized on the verb region of the sentence (e.g., “turn down”), but not on the preverb-, postverb-, and sentence-final regions. This pattern of results allowed researchers to hypothesize that maintaining focus on the action by following the verb with an adverb implying action might cause motor resonance to affect both the verb and the adverb that follows it. This prediction was tested in subsequent studies that fall within the second line of research addressing the role of linguistic focus in simulation of action during processing of language.

2.3.2.2. The role of linguistic focus in action simulation during language comprehension

This line of research aims to investigate whether linguistic focus helps to identify the dynamics of action simulation within a sentence. For instance, Taylor and Zwaan (2008), using the same experimental paradigm as in Zwaan and Taylor (2006), asked participants to read sentences in which the verbs were followed by adverbs that either kept focus on the action (e.g., "When he saw a gas station, he exited *slowly*") or on the agent (e.g., "When he saw a gas station, he exited *eagerly*"). The principal finding was that motor resonance affected both the verb and the adverb that followed it, but only when the postverbal adverb maintained focus on a matching action. In another recent study Masson, Bub, and Lavelle (in press) investigated whether shifting the focus from proximal goals of the agent to distal goals of the agent affects the dynamics of motor resonance in sentence comprehension. More broadly, researchers asked participants to perform a cued reach and grasp response while listening to sentences that described a functional motion (executed to use an object for its intended purpose, and thus corresponding to a reach response) and a volumetric motion (executed to pick up an object, and thus corresponding to a grasp response). The major result was that duration of motor resonance was evanescent when sentences described the proximal intention first (e.g., "John lifted the pencil to clear the desk") and persistent when sentences described the distal intention first (e.g., (e.g., "To clear the desk, John lifted the pencil"). Masson et al. (in press) interpreted this finding as evidence of hierarchy between the two types of actions, suggesting that the focus of volumetric movements is limited to a word denoting an object and the focus of functional movements extends to other regions of the sentence (also see Bub & Masson, 2012, for discussion of similar evidence using word stimuli).

2.3.2.3. The role of grammar in action simulation during language comprehension

There is now a growing literature showing that grammar may also affect the prevalence of simulation in sentence and discourse processing. For instance, Zwaan, Taylor, and de Boer (2010), using a similar paradigm as in Zwaan and Taylor (2006), incorporated manual rotation sentences into stories about bank robbery. Three types of target sentences were used: the sentences describing actions performed in the past, the sentences describing actions being performed, and the sentences describing actions intended to be performed. The major result was that motor resonance occurred only for the sentences implying past and present actions. The researchers concluded that no significant activation of compatible motor responses occurred for the sentences describing future actions due to the fact that these sentences focused on preparation rather than execution of action. The role of grammar was further specified in other related studies. For instance, Ditman, Brunye, Mahoney, and Taylor (2010) showed that memory was better for sentences preceded by pronoun "you" rather than by pronouns "he" or "I". In another interesting research, de Vega, Robertson, Glenberg, and Rinck (2004) and Santana and de Vega (in press) demonstrated that comprehension of participants who read sentences describing simultaneous actions by means of the temporal adjective "while" was impaired relative to comprehension of participants who read sentences implying successive actions by means of the temporal adjective "after ".

2.3.2.4. The effects of gesture representations on sentence comprehension

Kaschak and Glenberg (2002), Zwaan and Taylor, and many others (e.g., Boreggine & Kaschak, 2006; Kaschak & Borregine, 2008) showed that compatibility between literal direction of hand motion and that implied by the sentence facilitates sentence processing. Researchers such as Masson, Bub, and Warren (2008) and Bub, Masson, and Cree (2008) extended these findings by demonstrating that more specific action representations based on the type of action associated with a referent in a physical world are evoked during sentence processing. For example, Masson, Bub, and Warren (2008) developed a procedure to measure the dynamic representation of functional and volumetric hand actions implied by the sentence. They constructed a response apparatus that consisted of shapes associated with certain hand actions (e.g., horizontal grasp, horizontal pinch, vertical grasp, vertical pinch) and trained participants to produce hand actions that corresponded to those depicted in the picture (each picture depicting a hand action signaled a particular action on the apparatus). After the training session, participants listened to sentences, each referring to a certain object (the verbs used in these sentences denoted either attention/movement toward an object as in "A lawyer kicked a calculator", or a non-manual interaction with it as in “A lawyer looked at a calculator”), and immediately after made speeded responses to the pictures that appeared on the screen by lifting the hand from a button box and manually carrying out the corresponding action on the apparatus. The results showed that functional and volumetric actions were activated during comprehension of sentences that stressed interaction with objects (e.g., kick a calculator). Moreover, motor resonance occurred (functional motion was activated) even during comprehension of sentences that referred to non-manual interaction with objects (e.g., look at a calculator). The researchers interpreted their findings as suggesting that the relationship between a constructed sensory-motor simulation and the meaning of the sentence can be quite specific. That is, sentence processing may arise not from a literal meaning of the sentence, but from prior experience that best captures the functional and volumetric properties of the object (i.e., moving a calculator by hand rather than kicking it by foot).

2.3.3. Summary

From what was reviewed so far, it is evident that the case of perceptual and action simulations is strong in the area of concrete language processing. The researchers approach the importance of embodiment by either amplifying evidence for the activation of embodied representations in language comprehension, or establishing boundary conditions that define the prevalence of simulation in understanding of language. As discussed previously, such boundary conditions can be temporal overlap and integratability in the domain of perception, and linguistic focus and grammar in the domain of action. Finally, as this part of literature review has shown, several researchers made replications of original studies (e.g., Pecher & Zwaan, 2012; Santana & de Vega, in press) to build stronger theoretical conclusions. Indeed, replication studies are important for the current research as they help remove biases that can be inherent in a single experiment. The “embodiment” literature is quite large in the domain of concrete language processing and increasing generalisability of findings is an essential next step in this kind of research.

2.4. A review of evidence on processing of language describing abstract concepts

There is little question that sensory-motor simulations play important roles in the process of concrete language comprehension. However, an increasing number of researchers begins to challenge the adequacy of embodiment theory by asking how humans understand abstract concepts that by definition have no physical referents and are not easily imageable (e.g., Dove, 2009; Mahon & Caramazza, 2008; Pezullo & Castelfranchi, 2007). Indeed, the number of studies addressing the role of embodiment in concrete language processing outweighs the number of studies addressing the role of embodiment in abstract language processing. On balance, is also fair to say that the supporters of embodied account of cognition have already provided enough empirical support suggesting that sensory-motor simulations are at least somewhat involved in processing of abstract language as well as identified the theoretical approaches that explain how abstract language is grounded (see Pecher, Boot, & van Dantzig, 2011, for a review). Acknowledging the importance of this topic, this section reviews how several recent papers tackle the problem of abstraction with respect to processing of emotion, time, quantity, transfer, and metaphorical action.

2.4.1. Emotion

An increasing amount of research has been conducted to test whether reenactment of a congruent (or incongruent) emotional state affects language comprehension. For example, Havas et al. (2007) asked participants to read sentences describing emotional or non-emotional events while being in a matching or mismatching emotional state. The major result was that sentences describing pleasant events were processed faster when participants were smiling. Conversely, unpleasant sentences were processed faster when participants were prevented from smile. These results are in harmony with embodiment theory as they suggest that sentence comprehension is facilitated when the suggested mood of the sentence is congruent with the concurrent mood of the comprehender. In a different study, Havas et al. (2010) provided further evidence in support of emotion simulation. The participants were injected a botulinum toxin-A (BTX) to temporarily paralyze a facial muscle responsible for frowning. Later, they were instructed to read sad and angry sentences.

The researchers found that reading of sad and angry sentences was slowed after Botox injections. Again, this finding is consistent with embodiment theory which predicts that being prevented from frown makes it more difficult to simulate sadness and anger. Finally, Foroni and Semin (2009), using EMG measurement of the zygomatic major and cirrugator supercilii muscle regions, found that motor resonance was induced when participants processed adjectives describing emotion (e.g., happy, sad), but to a lesser extent than when participants processed action emotional verbs (e.g., to smile, to frown). Thus, it can be concluded that the effect of sensory-motor simulation is stronger for concrete emotional words than for abstract emotional words.

2.4.2. Time

The idea that time can be understood through front-back spatial representation (i.e., future is front; past is back) was extensively discussed in the literature (e.g., Boroditsky, 2000; Boroditsky & Ramscar, 2002; Genter, Imai, & Boroditsky, 2002; Lakoff & Johnson, 1980; Torralbo, Santiago, & Lupianez, 2006). In recent years, however, several studies presented a few additional novel findings that warrant discussion. For instance, Sell and Kaschak (2011) investigated whether time shifts are represented spatially in comprehension of texts describing past and future events. The participants read short texts sentence-by-sentence and after reading each sentence made sensibility judgments by either moving their hand from the start button to the response button (Experiment 1) or pressing the start and response buttons without moving the hand (Experiment 2). The major results were as follows. First, responses for sentences describing future events were faster when participants responded away from their body. Conversely, responses for sentences describing past events were faster when participants responded toward their body. Second, a spatial compatibility effect occurred only when participants moved their hand to produce a response (Experiment 1). Third, a spatial compatibility effect occurred only when the texts described a large time shift (a month), but not a small time shift (a day). As another example of how time can be understood through spatial representation, Santiago et al. (2007) presented participants with words located either to the left or to the right from the fixation point and then asked to judge if words referred to past or future events. The major finding was that participants were faster in their responses when words referring to the past or future events were presented on the left side or the right side of the screen, respectively. Finally, Lakens, Semin, and Garrido (2011) extended Santiago et al.'s (2007) findings by asking participants to indicate if words presented over headphones were louder on the left or right channel (note that words were presented equally loud binaurally). Consistent with the prediction, participants judged past words to be louder on the left channel and future words on the right channel. Thus, the researchers concluded that both auditory and visual (as in Santiago et al., 2007) judgments show a similar spatial bias. In brief, these findings suggest that the abstract concept of time is understood by way of analogy to representation of embodied experiences of space either along the front-back or left-right axis.

2.4.3. Quantity

There is mounting evidence that the concept of quantity can also be grounded in spatial representations. For instance, Dehaene, Bossini, and Giraux (1993) asked participants to indicate whether numbers presented on a monitor were odd or even with a left or right hand. The researchers found that participants were faster to respond to odd or even low digits (e.g., 1 or 2) when responding with a left button press, and faster to respond to odd or even high digits (e.g., 8 or 9) when responding with a right button press. This effect was coined the Spatial Numerical Association of Response Codes (SNARC). Dehaene et al. (1993) interpreted their finding as evidence that the concept of quantity is understood as a mental number line along the left-right axis. SNARC effect was also observed for phoneme detection of digits' names (Fias, Brysbaert, Geypens, & d'Ydewalle, 1996), digit magnitude classification (Bächtold, Baumüller, & Brugger, 1998), and even for ordinal stimuli such as days of the week, and months of the year (Gevers, Reynvoet, & Fias, 2003, 2004). In a most recent study, Sell and Kaschak (2012) advanced our understanding of this effect in two important ways. First, they investigated the usefulness of spatial representations in the comprehension of the concept of quantity on a more global text level. Second, whereas previous work provided evidence that the concept of quantity is represented along the left-right axis, their research explored whether quantity is understood along the metaphor-based up-down axis (i.e., more is up, less is down). To assess these questions, the researchers asked participants to read (Experiment 1) or listen to (Experiment 2) short stories sentence-by-sentence (e.g., “Much/Less runs were being scored this game”). Participants indicated that they finished reading (listening to) the sentence by either releasing their hand from the button used to display the sentence and moving it to the response button aligned on the up-down or the right-left axis, or pressing the button used to display the sentence and positioning the other hand over the response button to terminate reading the sentence. The major finding was that reading times for sentences describing increases in quantity were faster when the response was made away from the body. Conversely, reading times for sentences describing decreases in quantity were faster when the response was made toward the body. Furthermore, responding was significant both when a participant moved and did not move to respond. No compatibility effects were observed along the non-metaphor-based left-right axis. Thus, this finding is consistent with the embodied account of cognition which predicts action-space (e.g., Boroditsky & Ramscar, 2002) and action-sentence compatibility effects (Glenberg & Kaschak, 2002) suggesting that language processing is grounded in bodily mechanisms of perception and action.

2.4.4. Transfer

In subsection 1.2.1 the evidence provided by Glenberg and Kaschak (2002) was reviewed indicating that comprehension of sentences describing transfer of objects influenced the motor event that followed. In the same study, as well as a more recent study of Glenberg, Sato, Cattaneo, Riggio, Palumbo, and Buccino (2008), it was demonstrated that the ACE effect also occurs during comprehension of sentences describing abstract transfer. More concretely, Glenberg et al. (2008) asked participants to read abstract sentences describing abstract toward (e.g., “Anna delegates the responsibilities to you”) and away transfer (e.g., e.g., “You delegate the responsibilities to Anna”) and judge the sensibility of sentences by responding in the direction that either matched or mismatched the direction implied by the sentence. The major finding was that judgments were faster when response direction and sentence direction matched rather than mismatched. Thus, it can be concluded that comprehension of sentences describing abstract transfer events requires the resources of simulation system to the same extent as comprehension of sentences describing transfer of objects.

2.4.5. Metaphorical action

A few studies demonstrated that compatibility between literal body action and metaphorical action improves language processing. For example, in one line of research Santana and de Vega (2011) investigated whether processing of sentences describing metaphorical actions modulates action systems. Participants read metaphors (e.g., “His talent for politics made him rise to victory”) and abstract sentences similar in meaning to the metaphors (e.g., “His working capability made him succeed as a professional”), and then performed a hand motion (while reading the sentence verb) that either matched or mismatched the direction connoted by the sentence. The results revealed that responding was faster when there was a match between the direction of literal movement and that implied by the sentence. In a different line of research, Wilson and Gibbs (2007) tested whether previous real and imagined body movement enhances comprehension of metaphorical phrases. Participants learned to make different body movements or imagined making a particular body movement and then were presented with metaphorical phrases (e.g., grasp a concept) that either matched or mismatched a previous body movement (e.g., grasping movement). The researchers found that phrase reading times were faster when the previous literal or imagined body movement was congruent with the action implied by the sentence. In another experiment, Gibbs, Gould, and Andric (2006) revealed that even watching someone make a congruent body movement induced comprehension of metaphorical phrases (e.g., watching someone make a stretching motion while processing the phrase “stretch for understanding”). For a more detailed discussion of these and similar findings see Gibbs (2006), and Gibbs and Perlman (2010).

2.4.6. Summary

In the light of the studies reviewed above, it can be argued that the proponents of embodied view of cognition have partially tackled the problem of abstraction. The researchers approach the abstractness problem in the following ways. The first approach is based on conceptual metaphor theory (Lakoff & Johnson, 1980; Lakoff, 1987). The basic idea is that abstract concepts are understood metaphorically through reference to a more concrete embodied experience. Here, the evidence has been provided how metaphorical use of space is used to represent such concepts as time and quantity. It is also worth noting that many other equally fruitful contributions (which were not discussed due to space limitations) demonstrated how social relations may be understood in terms of temperature (Ijzerman & Semin, 2010; Williams & Bargh, 2008), social status in terms of a vertical spatial axis (Schubert, 2005), morality in terms of cleanliness (Schnall, Benton, & Harvey, 2008), importance in terms of weight (Jostmann, Lakens, & Schubert, 2009), distance in terms of similarity (Boot & Pecher, 2010), categories in terms of containers (Boot & Pecher, 2011), and political attitudes in terms of a horizontal spatial axis (Oppenheimer & Trail, 2010; Farias, Garrido, & Semin, 2013). In brief, the case of conceptual metaphor theory in explaining abstract concepts is strong. The second well-established approach focuses on the importance of motor processes in comprehension. The primary evidence for this approach is the ACE effect first reported by Glenberg and Kaschak (2002). Here, the evidence has been reviewed on how transfer events, metaphorical actions, and emotions (see Glenberg, Webster, Mouliso, Havas, & Lindeman, 2009, for a detailed discussion on how emotion prepares the body for appropriate actions) can be understood through action schemas. The third approach (not reviewed here due to paucity of behavioral evidence), which has received little scientific attention compared to the other two approaches, suggests that people come to represent and reason about abstract concepts with the help of aspects of experience, including objects, agents, settings, and introspections, in which such concepts are grounded. As an illustration for this claim, Barsalou and Wiemer-Hastings (2005) in a feature generation experiment found that participants tended to associate abstract concepts with social aspects of experience and concrete aspects with physical entities, suggesting that comprehension of abstract concepts relies at least partially on situated simulations. For a discussion of recent evidence from neuroscience supporting this approach see Wilson-Mendenhall, Barrett, Simmons, and Barsalou (2011) and Wilson-Mendenhall, Simmons, Martin, and Barsalou (in press).

To conclude, empirical evidence demonstrates that comprehension of abstract and concrete language requires the resources of simulation system. Thus, as Niedenthal notes (2007), embodied comprehension can be compared to the experience of reliving the past event in some of its sensory, motor, and affective modalities. Annex A gives a brief overview of influential experimental studies that have come to drive discussions and debates in the field of embodied language comprehension. The table indicates independent and dependent variables of research, methods of data collection, and the main results. Because of space limitations, only studies on perceptual, action, and emotion simulation were included, and thus many other interesting findings are not listed in the table.

2.5. Embodied theories of language comprehension

In the previous section a large body of empirical findings was reviewed suggesting that embodiment representations get activated when individuals process the language describing concrete and abstract concepts. At the same time, many researchers have argued that a purely embodied approach to comprehension is not very promising, given that it overlooks alternative explanations complementary to mental simulation (e.g., Louwerse, 2007, 2011) and provides only a partial solution to the problem of abstraction (e.g., Dove, 2011). As a result of these criticisms, researchers such as Andrews, Vigliocco, and Vinson (2009), Barsalou et al. (2008), Dove (2011), and Louwerse (2007) put forward the theories suggesting that language processing arises both from sensory-motor grounding and relations between symbols. To assess the commonalities and differences between the various theories that have been proposed, a variety of old and new theoretical approaches are reviewed that support either a strong embodied or a moderate embodied view. Additionally, the empirical evidence that supports the claims of each theory shall be provided.

2.5.1. Theories that support a strong embodied view

Embodied theories supporting a strong embodied view argue that human cognition is completely grounded in sensory-motor systems. Four strong embodied theories currently drive discussions and debates in the field (listed in ascending order of the year published): Perceptual Symbol Theory of Barsalou (1999); Indexical Hypothesis of Glenberg and Robertson (1999, 2000); Immersed Experiencer Framework of Zwaan (2004), and Action-based theory (ABL) of Glenberg and Gallese (2012).

2.5.1.1. Perceptual Symbol Systems (PSS)

According to PSS theory of Barsalou (1999a), cognitive processes responsible for language comprehension use partial reactivations of sensory, motor, and affective systems to form meaningful mental representations. More broadly, during original experience of event, modality-specific areas of the brain capture patterns of activation from sensorimotor and introspective systems. Later, while thinking or remembering about the event, these modality-specific areas partially reactivate original perceptual representations (Barsalou, Simmons, Barbey, & Wilson, 2003).

This theory suggests that knowledge about the world is not developed in a holistic way. Instead it develops categorically when attentional system focuses on components of experience in the context of possible interactions with the world. The continuous experience with the world, in turn, leads to gradual integration of perceptual symbols into a distributed multi-modal system that represents the category as a whole – a simulator (see Barsalou, 2009, for further discussion). This way we develop various kinds of perceptual simulators (visual, motor, emotional, etc.) that later get integrated with simulators for the words they refer to. With such an approach to knowledge representation it is fairly easy, for example, to distinguish between orientation of a book on a shelf and orientation of a book on a table, and to discriminate between a sound of a voice in a cave and a sound of a voice in a living room during language comprehension. In brief, the possibility for interaction between language, body, and environment allows humans to make inferences about information that is not explicitly contained in language.

This theory has been corroborated by numerous experimental demonstrations. Here, just a smattering of evidence adduced to support this theory is provided. For example, Wu and Barsalou (2009) showed that participants reported higher accessibility to such internal properties as “seeds” or “red” while being asked to list characteristics of “half watermelon” than “watermelon”, suggesting that participants constructed perceptual simulations to generate properties of nouns and noun phrases. The importance of environment in constructing perceptual simulation was reported by Borghi et al. (2004). More concretely, the researchers found that participants were faster to attribute an object (denoted by a noun) to a certain location when the noun that referred to an object was available in the participant's perspective implied by a preceding sentence. That is, participants were faster to verify a noun "sign" when it was preceded by a sentence "You are waiting outside a restaurant" than a sentence "You are eating in a restaurant". Clearly, this finding suggests that cognition is situated and that people not only simulate the physical entities described in the sentence, but as well the environment around them. In another study, Pecher et al. (2003) showed that conceptual system is not amodal by asking participants to verify different-modality properties. More concretely, participants were first instructed to verify a property in one of the six modalities such as vision, audition, taste, smell, touch, and action (e.g., property "cool" for "marble" from touch modality). Second, everyone verified a property from a different concept that belonged to either the same or different modality (e.g., "sticky" for "peanut butter" vs. "squeaking" for "bed springs"). The task consisted in judging if the concept-property item was true of false. The results revealed that participants verified the second property presented on the screen faster if it followed the first property from the same modality. These results suggest that conceptual system is not amodal and that meaning is extracted from multimodal experience of the event or situation. Finally, the evidence on perceptual simulation reviewed in the Section 2.3 is also consistent with the PSS Theory.

2.5.1.2. Indexical Hypothesis (IH)

IH theory of Glenberg and Robertson (1999, 2000) is another theory of language processing that further develops Barsalou's (1999a) model by specifying those components of perceptual symbols that are related to action, and, in particular, to the function of action in comprehension of language. It was largely inspired by Glenberg's (1997) claim that a situation becomes meaningful depending on the set of actions available to a particular individual in a particular situation. For example, consider the sentence, "John sweeps the floor with a toothbrush." According to IH, first words and phrases in the sentence are indexed to analog objects, pictures, or perceptual symbols (Barsalou, 1999a) in the physical world. Second, possible combinations of interactions (affordances) with the objects are established. Because of affordances, we know that our sentence is sensible, given that it is physically possible to sweep the floor with a toothbrush even if this situation suggests that someone's day went very wrong. Third, language comprehension is coordinated by syntax that provides the reader with syntactic cues as to whether the objects and activities implied by the sentence can be successfully meshed.

Action-based specifications on language processing are all the more noteworthy as they demonstrate that one of the main functions of comprehension is preparing for situated action. Glenberg and Robertson (2000) developed the importance of situated action for language processing by presenting a challenge for computational models like LSA (Landauer & Dumais, 1997) in accounting for novel situations. More concretely, the researchers presented participants with a situation describing a problem (e.g., "Mike was freezing while walking up State Street into a brisk wind. He knew that he has to get his face covered pretty soon or he would get a frostbite. Unfortunately, he didn't have enough money to buy a scarf") and three sentences describing how a protagonist solved the problem: afforded (e.g., Being clever, he walked into a store and bought a *newspaper* to cover his face), non-afforded (e.g., Being clever, he walked into a store and bought a *matchbook* to cover his face), and related (e.g., Being clever, he walked into a store and bought a *ski-mask* to cover his face). The participants' task was to judge the sensibility of sentences. The major finding was that participants could easily distinguish between the three types of sentences, but not a symbolic machine like LSA that failed to distinguish between afforded and non-afforded sentences. This pattern of results led authors to conclude that meaning cannot emerge solely from interdependencies between the words as symbolic theories propose, given that concepts are often not semantically related.

2.5.1.3. Immersed Experienced Framework (IEF)

IEF theory of Zwaan (2004) is another theory of language processing the basic premise of which is that language is a set of cues people use to construct sensorimotor simulation of the situation. Under this account, language understanding is similar to dynamic immersion of the comprehender into the described situation by means of activating experiential representation of language symbols (lexical, grammatical, etc.) and associated experiential representations that refer to these symbols (perceptual, motor, emotional). This theory assumes that there are three major processes of language comprehension: activation, construal, and integration.

During activation, target words activate functional webs that are used during the original experience with the referent. By functional web is meant various experiences with referents in different visuospatial configurations such as orientation, shape, etc. (e.g., a bird in the sky with its wings outstretched and a bird in the nest with its wings drawn in). During construal functional webs are integrated in simulation of the event implied by language. Finally, integration refers to experientially-based transitions from one construal to another. These transitions can be, for instance, visual (e.g., scanning of the environment) in visual scenes or emotional (e.g., anger towards the protagonist) in static or dynamic scenes. Among the factors that influence successful integration are concordance with human experience, amount of overlap (refers to how much of current mental simulation has the same components of construal as the previous simulation), predictability (anticipation of next event), and linguistic cues (tense, word order, etc.). In sum, comprehension in Immersed Experienced Framework is based on the following three principles: (a) simulation of visuospatial characteristics of the objects implied by language; (b) integration of this simulation in the context of a specific event; and (c) meshing of different simulations based on personal experience, learning history, combinability, predictability, and grammatical markers.

The evidence for this theory was extensively reviewed in the Section 2.3 of this chapter regarding simulation of orientation, shape, visibility, and linguistic focus, and thus is not discussed here.

2.5.1.4. Action-based Language (ABL)

ABL theory of Glenberg and Gallese (2012) is a model of language processing that offers a new action-based account of language comprehension by making use of neurophysiologic findings on mirror (Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010) and canonical (Rizzolatti & Luppino, 2001) neurons, and by adopting controller and predictor models from theories of motor control responsible for computing goal-oriented motor commands and predicting sensorimotor effects of these commands (Grush, 2004; Wolpert, Doya, & Kawato, 2003). According to this theory, language comprehension is tantamount to predicting sensorimotor and affective effects of the performed action. For example, upon hearing the word “walk”, a person’s speech mirror neurons activate an associated action controller responsible for generating motor commands necessary for interaction. Later, the predictor (sensory, motor, or emotional) of the target word establishes possible consequences of the action to be performed. In other words, under this account the same hierarchical mechanisms that are utilized in controlling action (i.e., control and predictor) are then used for generating grammatical sequences in language processing. Importantly, Glenberg and Gallese (2012) make two explicit assumptions about their model. First, it is suggested that the model is not only limited to explanation of verbal instructions, but instead covers all parts of speech. Second, it is stressed that the motor system, though the most important contributor, acts in a well-coordinated manner with other bodily systems (e.g., perceptual system).

Given that ABL theory is a new theoretical account, empirical evidence in support of it is admittedly quite thin. However, the available evidence that at least partially supports the claims of Glenberg and Gallese's theory (2012) leads to conclude that this approach is promising. Consider, for instance, the work of Masson et al. (2008), which was described in subsection 2.3.2.4 of this article, and the work of Masson, Bub, and Newton-Taylor (2008). The researchers hypothesized that comprehension of sentences like "John looked at a calculator" or "John forgot the calculator" would evoke the physical forces required to use the described object. In line with the prediction, functional actions (referring to a situation when an object is used for its intended purpose) were primed when participants were processing these sentences. What makes this finding stand out is that motor resonance occurred during comprehension of sentences describing concepts that have no action associations and ABL is the only embodied theory that explicitly acknowledged the role of action in comprehension of language that does not describe any form of physical interaction.

2.5.2. Summary

Contrary to amodal view that often places human cognition on the same footing as computer intelligence (Niedenthal et al., 2005), outlined embodied theories of language comprehension suggest that the environment, situations, the body, and simulations in the brain's modality-specific systems ground core cognitive representations. The major claim that stays at the heart of these theories is that language comprehension cannot be a product of redescription or translation of amodal symbols. Apparently, strong embodied theories are mutually reinforcing accounts of language processing. For example, Perceptual Symbol System of Barsalou (1999a) shows similarities with Indexical Hypothesis of Glenberg and Robertson (1999, 2000) in that both accounts suggest that language comprehension operates on perceptual simulators. While Barsalou (1999) explains why perceptual simulators stay in the core of human conceptual system, Glenberg and Robertson (1999, 2000) replace the discussion by looking into action-based mechanisms that ensure proper operation of such perceptual simulators. Similarly, Zwaan's (2004) Immersed Experienced Framework has much in common with Indexical Hypothesis, given that both models view comprehension in an incremental fashion. For instance, while Glenberg and Robertson (1999, 2000) suggest that sentences are understood through indexing, deriving affordances, and meshing, Zwaan (2004) proposes that sentence comprehension is achieved by activation, construal, and integration. The question could therefore be raised whether indexing is similar to activation, deriving affordances – to construal, and meshing – to integration. Though this question remains unanswered for now, it is noteworthy that the basic processes behind these three steps have a lot in common in both theories. Finally, Glenberg and Gallese's (2012) Action-based Language (ABL) model on the face of it seems to have little in common with other embodied models. At the same time, though providing an original and intriguing perspective, the basic idea behind this theory is in fact quite similar to common assertions of other theories – knowledge is simulated in the context of relevant actions.

2.5.3. Theories that support a moderate embodied view

An increasing number of researchers have proposed that language processing arises both from sensory-motor simulations and interdependencies between the words. Here, Language and Situated Simulation Theory of Barsalou et al. (2008) and Symbols Interdependency System of Louwerse (2007) that support such a view are reviewed.

2.5.3.1. Language and Situated Simulation (LASS)

LASS theory of Barsalou et al. (2008) suggests that multiple systems are involved in language processing: symbolic systems, simulation systems, and statistical representations that are involved in the processing of both language and simulation. In their work, the authors offer an account of language processing postulating that simulation system represents deeper conceptual processing comparing to the linguistic system. In particular, it is proposed that at the onset of language comprehension both systems (linguistic and simulation) get activated, but the linguistic system peaks first. At this stage, words are being recognized and associated linguistic forms are produced (e.g., “tree” is associated with “trunk”, “branches”, etc), which allows an individual to support shallow processing of information. Next, the word’s representation activates simulations in the modality-specific systems, which allows an individual to represent the word in different situations, and thus engage in a deeper conceptual processing, compared to the purely linguistic processing. Therefore, when simulation is more dominant in reading comprehension tasks, people deeply process the text and form a wide number of inferences. On the contrary, when linguistic processing dominates, comprehenders appear to form shallow meaningful representations and tend to extensively rely on information explicitly given in the text. Importantly, Barsalou et al. (2008) assume that linguistic processing dominates under the conditions when people do not have to comprehend the text deeply. In contrast, simulation system dominates when linguistic system is not capable of supporting adequate performance alone. Finally, one of the most important assumptions of LASS theory is that linguistic system does not have enough power to implement symbolic operations without involvement of simulation system because it (linguistic system) manipulates linguistic forms rather than linguistic meanings.

The claims of LASS theory were tested in the recent studies of Santos, Chaigneau, Simmons, and Barsalou, (2011) and Simmons, Hamann, Harenski, Hu, and Barsalou (2008) which confirmed the prediction that comprehension originates in two systems – linguistic and simulation. For instance, in a study of Santos et al. (2011) participants were asked to generate properties for cue words that belonged to different conceptual domains. The major finding was that the properties describing highly associated concepts (e.g., a tree, a trunk, etc.) were produced earlier, compared to the other less associated properties describing situations and objects. This pattern of results suggests that the linguistic system peaked first and activated the associated linguistic forms. Then, the simulation system came into play and its activation was more slowly than the activation of the linguistic forms. Notably, these results are fully consistent with the predictions of LASS theory.

2.5.3.2. Symbol Interdependency System (SIS)

SIS theory of Louwerse (2007) is a quite similar account of language comprehension to Barsalou et al's. (2008) LASS theory in that it also addresses to what extent language comprehension is symbolic and embodied. Under this integrative account, language developed as a communicative short-cut for people to exchange knowledge (Louwerse, 2011). With this in mind, this theory suggests that in everyday language comprehension not all language symbols have to be grounded as much of the meaning comes from the relations between linguistic symbols. However, in some cases grounding is necessary to derive meaning. This is particularly the case when people have to process the information about spatial orientation or visual rotation that cues deep cognitive processing (see Louwerse & Jeuniaux, 2008, 2010, for discussion).

The claims of this theory were tested in a study of Louwerse (2008) as well as others (e.g., Louwerse & Jeaniaux, 2010; Louwerse and Connell, 2011). For instance, Louwerse (2008), using a computational disembodied machine like LSA, replicated Zwaan and Yaxley's findings (2003) regarding perceptual simulation in comprehension of spatial position and argued that perceptual relations are already encoded in language and are used by the comprehenders to derive meaningful representations. More broadly, using statistical linguistic frequencies obtained from the Web 1T 5-gram corpus (Brants & Franz, 2006), consisting of 1 trillion words (13,588,391 types) from 95,119,665,584 sentences, the author demonstrated that the frequency of higher objects preceding lower objects was significantly higher than lower objects preceding higher objects. Louwerse (2008) concluded that these results are not surprising, given that individuals typically do not say "down and up" or "toe and head", but rather use these phrases in reverse word order, pointing to the conclusion that frequency of word order is an important factor in language comprehension that cannot be dismissed. Additionally, in the second experiment of the same study, participants were asked to rate the likelihood that one concept appeared above the other (ratings were made on a scale of 1–6, with 1 being extremely unlikely and 6 being extremely likely) and it was revealed that average participants' ratings correlated significantly with the word pair frequencies from the first experiment. Thus, Louwerse (2008) concluded that the comprehenders also use the interrelations between symbols to process language rather than only simulations.

Louwerse and Jeuniaux (2010) and Louwerse and Connell (2011) extended the findings of Louwerse (2008) by investigating the conditions under which embodiment and linguistic factors determine performance. For instance, in the study of Louwerse and Jeuniaux (2010) participants were requested to make speeded judgments with regard to whether word pairs or pictures were semantically or iconically related. The embodied factor was tested by manipulating the relative position of words (e.g., attic presented above the basement) and the linguistic factor was tested by analyzing the frequency of the stimulus pairs in language. Among other findings, the researchers found that the embodiment factor was stronger in iconicity judgments for pictures and the linguistic factor – in semantic judgments for words, suggesting that the prevalence of one system over the other depends on the nature of the task and stimuli. At the same time, the authors noted that both factors predicted response time for semantic and iconicity judgments, pointing to the conclusion that both systems, embodied and linguistic, contributed to processing of words pairs.

2.5.4. Summary

In sum, moderate embodied theories are quite alike in that they propose that language comprehension is both symbolic and embodied. Both Language and Situated Simulation Theory (LASS) of Barsalou et al. (2008) and Symbol Interdependency System of Louwerse (2007) suggest that linguistic system dominates in the tasks that do not require deep processing of information (shallow comprehension) and simulation system dominates in the tasks where linguistic system is not capable of deriving meaning alone (deep comprehension). At the same time, whereas LASS theory assumes that symbolic mechanisms always utilize resources of simulation system to derive meaning (Santos et al., 2011), Symbol Interdependency hypothesis proposes that symbolic system alone can successfully cope with most of general comprehension tasks. See Annex B for a more detailed comparison.

2.6. The usefulness of embodiment for language processing

Despite considerable empirical and theoretical evidence in support of embodiment account, many scientists still suggest that sensorimotor simulations are insufficient to model meaning because their role in language comprehension is epiphenomenal (Landauer, et al., 1998). Similarly, many other researchers argue that sensorimotor experiences are already encoded in language, and thus do not need to be grounded (Kintsch, 2008; Louwerse, 2007). Acknowledging the seriousness of this question, in the remainder of this section five arguments will be laid out to suggest the importance of embodiment in language comprehension.

2.6.1. Evidence on processing of concrete concepts

As reviewed in sections 2.3 and 2.4, much empirical evidence have illustrated how sensorimotor and emotion simulations can implement language comprehension. In particular, it was shown that experimental manipulation with the bodily systems leads to a better language processing (e.g., Glenberg and Kaschak, 2002). However, if the role of the body was indeed epiphenomenal, should we observe any significant effects in behavioral performance by experimentally manipulating it? The brief answer is that we should not. Likewise, the reviewed behavioral studies have indicated that not only explicit properties of objects described by the sentence are part of the simulation process, but as well implicit properties such as shape or size (e.g., Zwan et al., 2002). However, if meaning merely arose from interdependencies between the words as amodal theory suggests, how would individuals process the situation that is expressed implicitly beyond words mentioned in the text? Unfortunately, this question also remains unanswered by now. For further related evidence not included in the review of present research, see Connell (2007) on perceptual information of object color, Glover and Dixon (2002) on simulation of size, and Alloway, Corley and Ramscar (2006) on the role of spatial environment.

An explicit focus of this chapter on behavioral findings might leave an impression with a reader that behavioral findings are not corroborated by the findings from neuroscience or other related disciplines. However, as it will be described next this impression appears to be incorrect. For example, in a rather interesting kinematic study, Gentilucci and Gangitano (1998) investigated the influence of automatic word reading on processes of visuo-motor transformation. More precisely, in this study participants were requested to reach and grasp a rod (position of the rod and size varied during the experiment) on the visible face of which the adjectives “long” and “short” were printed. Importantly, word reading was not explicitly required. Four markers were used to study the reaching and grasping components. The first marker was placed on the wrist to study the reaching component and the second and third markers were positioned on the nails to study the grasping component. The fourth marker was placed 8 cm away from participants’ sagittal plane and used as a reference point. See Figure 3.1 for a photographic presentation of the stimuli. According to embodiment theory, the meaning of language is related to human action, and thus high-level cognitive processes responsible for understanding of adjectives denoting distance should affect motor systems of the body.

Remarkably, that is just what was reported: adjectives denoting size had an impact on the reaching component of grasping movements by activating a motor program for a farther or nearer position of target object. That is, participants associated the word meaning with the distance to be covered. No effect of the adjectives on the grasp component was detected.

Figure 2.5. Photographic presentation of the stimuli used in the work “Influence of automatic word reading on motor control” by M. Gentilucci and M. Gangitano, 1998, *European Journal of Neuroscience, 10.*

Finally, behavioral and kinematic evidence on presence of embodied representations in language understanding is well-supported by neuroscientific findings. For example, if the role of the body was not central, should performance in a lexical decision task on words denoting arm or leg movements be facilitated when arm or leg areas in the left hemisphere receive transcranial magnetic stimulation? The brief answer is that it should not. However, recent evidence indicates the contrary (Pulvermüller, Hauk, Nikolin, & Illmoniemi, 2005). Similarly, should sensorimotor cortex get activated when people process the language describing movements in the absence of real body movements? Again, the answer is that it should not. But the evidence from brain-imaging studies demonstrates such an activation (e.g., Decety et al., 1994). Finally, the most recent studies showed that the activation of motor systems occurs immediately after the presentation of stimuli (Pulvermuller, 2008), ruling out the hypothesis that motor effects are the products of motor imagery after the comprehension process is completed.

In summary, embodied theories have a strong behavioral, kinematic, and neuroscientific support for the presence of modality-specific symbols in cognition relative to amodal theories that provide little direct empirical evidence on the presence of amodal symbols in the brain (see Semin & Smith, 2008, for discussion). This strong empirical case from multiple disciplines allows concluding that embodiment is necessary for concrete language processing.

2.6.2. Evidence on processing of abstract concepts

The most persistent objection to theories of embodiment is that they are not capable of explaining how all abstract concepts are processed. While this objection has merit considering that evidence on abstract concepts is still scarce and limited to specific domains, it is worth acknowledging that the supporters of embodied account of cognition has made a significant advance in the treatment of this problem by suggesting several approaches how abstract concepts can be grounded. In subsection 2.4.6 these approaches were mentioned, but not with the depth which could be convincing. Therefore, in the remainder of this section each of the approaches is explained in more detail.

The first approach is represented by work on metaphor (e.g., Gibbs, 1994; Gibbs & Steen, 1999; Johnson, 1987; Lakoff, 1987; Turner, 1996). For instance, Lakoff and Johnson (1980) suggest that a concrete concept like “food” may represent an abstract concept like “idea” (e.g., “That’s food for thought”), a concrete concept like “spark” may represent an abstract concept like “love” (e.g., “There’s a spark between them”), and an abstract concept like “gold-digger” may represent an abstract concept like “wealth” (e.g., “She’s a gold-digger”). In other words, abstract concepts are understood through metaphorical mappings. Similarly, Lakoff (1987) proposed that metaphors reveal how literal actions of people lead to invention of abstract concepts, suggesting that our body language is quite often consistent with our internal mental feelings. Indeed, we drum fingers when feel impatient, scratch out nose when feel uncertain, wink to express intimacy, or cross our arms to protect ourselves.

Research in social psychology has adduced a tremendous amount of evidence that at least partially supports the major claim of the conceptual metaphor theory: abstract concepts are understood by way of analogy to more concrete experiences. Consider just a smattering of some of the most interesting findings on attitude formation. Wells and Petty (1980) found that participants’ attitude toward a persuasive message was more positive when they had previously nodded the head, than when they shook the head or made no head movements. Thus, a head movement may be associated with either *positive* or *negative attitude*. In a similar study of Tom, Pettersen, Lau, Burton, and Cooke (1991) participants were instructed to nod or shake their heads while listening to music. While they listened to music, a pen lay on the table in front of them. Upon exit, when offered to take a pen, participants who were nodding the head preferred the original pen and participants who were shaking the head – the new pen. Thus, head movements may increase a person’s intuition about the correct *choice*. Oppenheimer and Trail (2010) asked participants (American citizens) to indicate their political views while having them sit in a chair that was purposely slanted (either to the left or right). The researchers found that spatial orientation influenced participants’ political attitudes. More concretely, participants who were oriented to their right gave preference to conservative political attitudes and participants who were oriented to their left – to liberal political attitudes. Thus, a concept like *political affiliation* may well be implemented by spatial orientation of the body. In a study of Chen and Bargh (1999) upon receiving positively or negatively valenced words, participants responded faster to positive words when pulling the lever toward them (a sign on affiliation) as well as to negative words when pushing the lever away (a sign of alienation). Thus, a concept *negative* can be associated with a literal movement of pushing something away from the body, and a concept *positive* with pulling something toward the body. In another related study of Förster (2004) participants provided higher ratings for positively valenced products when they flexed their arms during evaluation and lower ratings for negatively valenced products when they extended their arms during evaluation. Thus, an abstract concept *better* may be associated with a movement required to flex an arm and an abstract concept "worse" – with a movement required to outstretch an arm.

Among other interesting social psychology findings that relate to abstract concepts, it is worth mentioning the following studies. Wiesfeld and Baresford (1982) demonstrated how an abstract concept such as *proud* may be developed in the context of educational experience. In particular, it was demonstrated that upon receiving good grades, high school students adopted a more erect posture than upon receiving bad grades. Bargh, Chen, and Burrows (1996) revealed how an *elderly* abstract concept may be developed in the context of experience with other objects. In this experiment participants were asked to form sentences with such words as "wrinkle", "Florida", "knits" related to a category of words describing old people. Next, upon finishing the task, participants were asked to walk from laboratory to the elevator. It was found that participants who were primed with words describing elderly stereotype took more time to walk than participants in the control condition.

Finally, the work on spatial representations revealed that people make congruent gestures when speaking about time (Casasanto & Lozano, 2006), change thinking about time when are primed with different spatial perspectives (Boroditsky, 2000; Borositsky & Ramscar, 2002; Casasanto & Boroditsky, 2008) and take more time to make simple hand movements inconsistent with the meaning of abstract concepts (Casasanto & Lozano, 2007). For complete reviews of these and similar findings see Briñol and Petty (2008) and Niedenthal et al. (2005).

The second approach is associated with the work of Glenberg and Kaschak (2002), suggesting that processing of both concrete ("You give Art the pencil" and "Art gives you a pencil") and abstract ("You delegate the responsibilities to Anna" and "Anna delegates the responsibilities to you") language requires the simulation of action. More concretely, in this experiment participants were faster to judge a sentence as sensible when the direction of response matched the direction implied by sentence. A similar finding on abstract sentences was found in Glenberg et al. (2008). Put differently, this approach suggests that concrete transfer provides sensory-motor grounding for abstract concepts (Pecher et al., 2011).

The third approach is represented by Barsalou's (1999) Perceptual Symbol System. According to this theory, abstract concepts are understood in the context of situation in which they are used. Just like concrete concepts, abstract concepts consist of components of neural activity in multimodal systems (e.g., auditory, touch, motor, etc.). Consider, for instance, how Wilson-Mendenhall, Simmons, Martin, and Barsalou (in press) describe the representation of emotional abstract concepts in conceptual processing:

> We further assume that a specific emotion concept contains a large set of situated conceptualizations that produce emotion in many different kinds of situations, with each situated conceptualization producing a different form of the emotion. Consider one possible situated conceptualization associated with fear, where a runner becomes lost on a wooded trail at dusk. In this situated conceptualization, concepts for forest, night, animals, thirst, confusion, and many others become integrated meaningfully to represent fear, including the associated internal experience and potential actions. Consider another possible situated conceptualization associated with fear, where someone is unprepared to give an important presentation at work. In this situated conceptualization, a different set of concepts represents the situation, including presentation, speaking, audience, supervisor, and many others. Again, the integrated representation of diverse concepts into a situated conceptualization constitutes an instance of fear, including associated internal experience and action.
>
> From this perspective, fear cannot be understood independently of an agent conceptualizing his- or herself in a particular situation… Fear can look and feel quite differently in different instances. When you fear a flying cockroach, you might grab a magazine and swat it; when you fear disappointing a love one, you might think of other ways to make them feel good about you; when you fear a mysterious noise late at night, you might freeze and listen; when you fear giving a presentation, you might ruminate about audience reactions or over-prepare; when you fear getting a flu shot,

> you might cringe anticipating the pain; when you fear hurting a friend's feelings, you might tell a white lie. Sometimes you will approach in fear, and sometimes you will avoid. Sometimes your heart rate will go up, and sometimes it will go down. Whatever the situation demands (Wilson et al., in press).

Generally, this approach suggests that people come to represent and reason about abstract concepts with the help of aspects of experience, including objects, agents, settings, and introspections, in which such concepts are grounded. For instance, analyzing data using multiple regression or hierarchical linear modeling can lead someone to believe that statistics is really *difficult*. Similarly, increased heart beating, sweating palms, mirroring verbal and non-verbal patterns may suggest that someone is in *love*. Moreover, this approach suggests that there cannot be a stable image of any abstract concept, considering that any other abstract concept may mean different things to different people (e.g., some may consider sex a synonym to love and others consider sex merely as a rush of hormones).

In summary, it is true that we are still far from a unified embodied approach to comprehension of abstract concepts. However, the existing empirical evidence in support of embodied abstract language processing should not be overlooked or dismissed, and thus warrants discussion and future investigation.

2.6.3. Predictive power of simulations

Frequently in the literature it is possible to find the reasons why amodal account of cognition remains the dominant theory of knowledge representation. For example, along different lines, Niedenthal et al. (2005) mentioned possible explanations for the power of amodal symbols in ability to account for important functions of knowledge (e.g., categorization, language, thought, etc.), in ability to allow computers to implement knowledge (e.g., programming language), and in ability to be applied in intelligent systems in industry, education, and medicine. The authors also offered an explanation for the wide acceptance of amodal symbols by cognitive science based on absence of any alternative theory until recently. In brief, amodal theories provide experimenters with powerful tools to explain many psychological processes.

Nonetheless, while amodal system theory successfully explains many findings in cognitive science, embodiment theory both predicts and explains evidence for modality-specific simulations in cognition. Consider research reviewed in the previous chapter of this thesis suggesting that sensorimotor and emotion simulations imply such predictive power. For example, in a study of Zwaan et al. (2002) participants read sentences that described animals or objects implying different shape (e.g., “The ranger saw the eagle in the sky”; “The ranger saw the eagle in its nest”). After each sentence, participants saw a picture of animal or object that differed in shape (e.g., eagle with outstretched wings; eagle with folded wings) and had to decide whether the picture represented a word implied by the sentence. The results showed faster responses for picture stimuli that matched property of shape with the sentence. The point is: a match advantage between a visual stimuli and spatial property implied by the sentence indicates that participants simulated the shape of the eagle during processing of language in order to predict the correct meaningful representation of the sentence.

Similarly, research in the domain of action demonstrates that participants used simulations to predict meaning. For instance, in a study of Glenberg and Kaschak (2002) language processing was facilitated when the action implied by the phrase (e.g., close the drawer) was consistent with the hand movement to make a response (movement toward the body). This means that participants simulated the appropriate action to predict the meaning of the phrase that describes bodily movement.

Finally, in the domain of emotion simulation the case of prediction is also strong. For instance, Havas et al. (2007) found that processing of sentences describing emotionally laden events (e.g., “You and your lover embrace after a long separation”) was facilitated when bodily states were prepared for processing of congruent emotions. That is, participants simulated positive emotion in order to predict the meaning of the sentence.

In summary, whereas amodal processing explains how meaning is produced, embodied processing both predicts and explains how meaning is coded and communicated by the comprehender.

2.6.4. Embodiment and predictions for novel situations

According to symbolic view of cognition language comprehension arises from interdependencies between abstract symbols. For example, it was already discussed in Section 2.2 that computational symbolic models like LSA rely on word co-occurrences and dimensional analysis of words in context. But this really just begs the question. If meaning in symbolic systems relies on what has already been experienced and described, then how do we derive meaning from new experiences? Imagine that you have just bought a new 5^{th} Generation Apple iPod touch and you read a review of this device to a 50-year-old woman who still has a rotary phone in her house and is not keen on modern technologies:

> The latest iPod touch 5th Generation takes the best features of the iPhone 5, like the taller 640x1136 pixel, 4-inch screen and the iOS 6 software update with Siri, and adds a few little quirks of its own, like a choice of coloured backs (black, grey, pink, yellow, blue and a sixth Product Red) and a new strap called an 'iPod touch loop'.
>
> Along the way the camera has been upgraded to an iSight camera with a built-in flash that's capable of 1080p video recording and the processor has been upped to a duel-core A5 chip, giving it twice the processing power of the previous single-core A4 chip. Both the screen size and the faster processor are important for gaming, but more of that later.
>
> Memory configurations have been simplified. The new 5th gen is available only in 32GB and 64GB flavours.
>
> Finally, the new iPod touch runs iOS 6, the latest version of Apple's mobile operating system in all its glory, which means that both Panorama – a new mode for taking panoramic photos, and Siri, Apple's intelligent voice-activated personal assistant, are available here.
>
> Note: neither of these two features work on a iPod touch 4th Generation running iOS 6 (Barlow, 2012).

It is reasonable to predict that no matter how many new features of the new device you list, a woman who has never used a similar device in her life would have problems figuring out the meaning of such terms as, for instance, “pixel”, “1080p video", or "duel-core A5 chip processor". Similarly, she would have problems imagining how such a new device looks like in general. The list of features about IPod touch that symbolic systems can generate might include things like IPod touch is a music and video player, is ultrathin, small in size, etc. At a glimpse, it may seem that this sort of feature lists is enough to derive a meaningful representation of the device. However, how would a woman know how exactly different this video player is from a tape video player she has at home? Similarly, if such player is small in size, then how would she understand that it functions in a different way from her old tape video player? To solve this problem, every feature of the device should be grounded in perceptual and action systems. That is, linguistic symbols should be indexed to perceived objects or previous experiences (Barsalou, 1999a; Harnad, 1990). Clearly, demonstrating the function of each feature to the same woman while she holds an IPod touch in her hands would considerably facilitate understanding of the information about the new device. After all, all user guides how to use a new device come with certain pictorial information on controls, features, accessories, etc.

A skeptic might argue, however, that the role of embodiment might be important, but only in cases when people experience a completely novel situation as the one described above. In other words, it can still be argued that if people experience a new situation that is similar to a previous related experience, a list of amodal symbols may provide enough contextual information to understand another novel situation. More concretely, a person who previously worked with an iPhone or iPod (these devices share some similar features with iPod touch) would have no problems figuring out what the new iPod touch has to offer and how it looks like. While this conclusion is theoretically possible, a few questions can still be raised. Isn't the information about such properties as, for instance, color or shape, encoded in memory in the form of perceptual symbols (Barsalou, 1999a) rather than amodal symbols? Is it really so easy to describe in amodal symbols such perceptual information of iPod touch as raw brushed aluminum color? Similarly, what about information regarding the curved edges of the device (i.e., property of shape)? More basically, even if all Apple devices were similar in size and shape, what evidence do we have to support a conclusion that contextual information from previous experiences is represented only in the form of amodal symbols? That is, assuming that a feature list captures some basic perceptual information, is it possible to conclusively state that it captures all the perceptual information we originally experience? The answer to this question remains unanswered by now, but the empirical evidence in the domain of perception strongly argues in favor of embodiment stance (see Section 2.3 for a revision of relevant findings).

Finally, Glenberg and Robertson (2000) and Kaschak and Glenberg (2000) explained how simulation accounts for comprehension of novel situations by putting forward a theory called "Indexical Hypothesis" (described in more detail in Chapter 2). According to this theory, comprehension proceeds in three cycles. During the first cycle, words and phrases are indexed to perceptual referents that are stored in memory as perceptual symbols (Barsalou, 1999a). During the second cycle, possible interactions with objects (affordances) are derived. During the third cycle, affordances are integrated according to syntax. For example, Glenberg and Robertson (2000) presented a challenge for computational symbolic systems like LSA in accounting for novel situations by presenting participants with the sentences presented in Table 3.1.

The task of participants consisted in making sensibility and envisioning judgments of each of the sentences in the scenario (i.e., afforded, nonafforded, related) on a scale of 1 (virtual nonsense) to 7 (completely sensible). The results revealed that participants could easily distinguish between the three types of sentences. Upon collection of data from participants, the researchers examined whether a symbolic machine like LSA would as easily predict the differences between afforded, nonafforded, and related types of sentences. Interestingly, LSA did not manage to predict the sensibility ratings, and thus was not able to distinguish between afforded and nonafforded sentences. This pattern of results led authors to conclude that meaning cannot emerge solely from interdependencies between the words as symbolic theories propose, given that concepts are often not semantically related and are not easily associated in everyday experience. Instead, Glenberg and Robertson (2000) argued that a sentence becomes meaningful when one indexes words to perceptual symbols and meshes affordances taking into account one's learning history and goals.

Table 2.3

Examples of Sentences Used in the Study of Glenberg and Robertson (2000) to Support Indexical Hypothesis in Predicting the Meaning of Novel Situations

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Example 1

Setting: Marissa forgot to bring her pillow on her camping trip.

Afforded: As a substitute for her *pillow*, she filled up an old sweater with **leaves.**

Nonafforded: As a substitute for her *pillow*, she filled up an old sweater with **water.**

Related: As a substitute for her *pillow*, she filled up an old sweater with **leaves.**

Example 2

Setting: Mike was freezing while walking up State Street into a brisk wind. He knew that he has to get his face covered pretty soon or he would get a frostbite. Unfortunately, he didn't have enough money to buy a scarf.

Afforded: Being clever, he walked into a store and bought a **newspaper** to cover his *face*.

Nonafforded: Being clever, he walked into a store and bought a **matchbook** to cover his *face*.

Related: Being clever, he walked into a store and bought a **ski-mask** to cover his *face*.

It is also worth pointing out that the above mentioned examples of sentences from Glenberg and Robertson's (2000) study demonstrate a strong case why cognition is situated. If one experiences a novel situation like finding a substitute for a pillow, he needs to be creative to find the way out of the situation. A leaf-stuffed sweater as a pillow is an example of such human creativity during the new experience. Being creative is perhaps one of the best examples what makes humans different from machines that are programmed.

2.6.5. Practical application of simulation theory

As mentioned in the previous chapter, one of the cornerstones of literature on embodiment is the argument that language processing can be used to guide effective action. This function of comprehension was used by the proponents of embodied cognition to suggest practical implications of simulation theory for reading instruction to children. For instance, Glenberg, Gutierrez, Levin, Japuntich, and Kaschak (2004) implemented a new technique for teaching reading comprehension to children called “Moved by Reading”. The purpose of this technique was to teach children how to map words and phrases to experiences and events in the outside world. In particular, this new kind of technique taught simulation in two stages: physical manipulation with the toys and imaginative manipulation with the toys. During the physical manipulation, children were asked to read a small text about certain situations (e.g., house) that was divided into a set of critical sentences. After reading each of such critical sentences, children were asked to act out the meaning of the sentence with the toys that were in front of them (e.g., chair, bed, wardrobe, etc.). Thus, reading the sentence “Bob sits on the chair beside the bed” required from the child to connect objects to words that referred to them, considering visuospatial configurations implied by sentence. The results of this technique speak for themselves. For instance, in Glenberg et al.’s (2004) study children who physically manipulated the objects while reading (were taught to simulate) recalled 62 % of the content of the story and children in the control condition recalled only 29 % of the content of the story. The advantage of condition when children were physically manipulating the toys was also found in the ability of comprehenders to correctly answer text-related inference questions. This advantage demonstrated a large effect size, Cohen’s d = .81.

During the imaginative manipulation, children were requested to merely imagine manipulating the toys. Remarkably, at this stage children performed comprehension-related tasks just as good as in the stage of physical manipulation. More specifically, children who engaged in physical and imaginative manipulations performed the comprehension task almost two standard deviations better than children who reread the same sentences from text and did not engage in any manipulation with the toys.

Similar results were found in other related studies of Glenberg, Goldberg, and Zhu (2009), and Glenberg, Willford, Gibson, Goldberg, and Zhu (2011) when "Moved by Reading" was used a web-based system. Interestingly, although haptic information associated with toys was no longer accessible to children in the web-based "Moved by Reading" system, the results revealed that acting out the meaning of sentences with the help of toys on a computer screen facilitated comprehension to the same extent as when a child was physically manipulating the toys. Moreover, the results of these two studies (Glenberg et al., 2009; Glenberg et al., 2011) advanced our understanding of the strength of "Moved by Reading" technique by demonstrating that computer-based manipulation with toys influenced language processing both immediately after reading the story and when story reading and comprehension task were separated in time (one week). The reported findings led experimenters to conclude that the use of text-relevant images in teaching children to read might potentially become a very successful educational technique.

Finally, the same technique proved to be effective for teaching listening comprehension to learning-disabled Native American children (see Marley, Levin, and Glenberg, 2007, for details). More precisely, in this study seventh-grade students with academic learning difficulties were asked to listen to four narratives in one of the three conditions: manipulate, visual, and control. In the manipulative condition students moved the toys to act out the meaning of sentences from the text. In the visual condition students observed how an experimenter manipulated the toys to represent the text's content. In the control condition students thought about the content of sentences from the stories. The obtained results were consistent with previous findings of Glenberg et al. (2004). That is, students in the manipulative and visual conditions performed better on comprehension and memory tasks relative to students in the control condition. In brief, outlined research demonstrated that successful reading or listening comprehension arises not from reproducing what was read or listened, but rather from performing situated activity related to the content of what the reading (listening) passage is about.

In sum, there is a good deal of evidence that simulation is necessary for language processing. This evidence has been found (a) in empirical work demonstrating that manipulation with the body affects underlying performance, (b) in predictive power of embodiment indicating that simulations help to predict the meaning of the message, (c) in the power of embodiment to explain novel situations, and (c) in the applicability of embodied theories to education. Clearly, as a new scientific paradigm embodiment theory of language comprehension requires further theoretical and empirical consideration, and thus it is not surprising that it has not yet been fully accepted by cognitive scientists. At the same time, given an emerging focus on interactions between bodily states and language processing, it is very likely that this new kind of approach could shed some light on the phenomena that have been traditionally difficult to explain using amodal theories of cognition.

2.7. Summary

This chapter began with a review of principles that lie at the heart of symbolic and embodied approaches to language comprehension. It was noted that an amodal account of cognition, which suggests that language processing comes from a manipulation of abstract symbols, does not always manage to derive meaningful mental representations. In contrast, an embodied account of cognition offers a solution to this problem by proposing that language processing is not amodal, but is instead grounded in the perceptual, action, and introspective systems. In this way, comprehension involves sensorimotor and introspective simulations to represent knowledge that is situated in the context of relevant environments, goals, experiences, and background situations. To assess such an account of cognition, major embodied empirical findings and theories were reviewed as well as the arguments supporting the importance of sensory-motor grounding for language processing. The most general conclusion that can be drawn is that sensorimotor activation is necessary for language processing. At the same time, in the light of reviewed findings and theories it is fair to say that the supporters of embodied view of cognition are still far from an agreement whether simulation is the most important contributor to language comprehension or not.

2.8. Research questions

This broad overview of the relevant literature on embodied language comprehension provides a jumping-off point for the four research questions that follow.

First, as demonstrated by this review, most empirical evidence on the role of bodily feedback in language processing has been supported by the experiments conducted at the level of word or sentence. In contrast, the case for sensorimotor and introspective simulations at discourse level has received little scientific attention. This poses a serious challenge for the current investigations in the field as in real-life settings most of the comprehension proceeds in the form of discourse that is not isolated from a situation (Sparks & Rapp, 2010). It is fair to say that a modest amount of research in the field of reading comprehension has demonstrated that embodied representations can influence discourse processing. For example, studies focusing on neural substrates of narrative comprehension showed that modality-specific areas of the brain involved in imagining and manipulating hand movements increased in activation when participants read about character's interactions with objects (Speer, Zacks, Reynolds, & Hedden, 2005). Similarly, in eye-tracking studies (Spivey & Geng, 2001) it was demonstrated that eye movements of the readers "followed" the description of the events implied by discourse. However, it is also fair to say that the evidence for activation of embodied representations at discourse level is still scarce and far from being conclusive. Therefore, a key question that has motivated all the experiments in the following chapters is as follows: Does embodiment affect language processing on a more global discourse level? This question was investigated in the experiments one to five by collecting reading times as readers normally read the text while their bodily states were manipulated and asking participants to fill in the posteriori questionnaire.

Second, as the review of the literature has shown, major research on embodiment effects in sentence processing mostly tested the role of modality-specific simulations using "online" measures of comprehension such as collecting reading times or recording gaze durations. However, as discussed previously, such "online" measures do not take into account important "offline" mental representations that are established after the reading process is completed (Graesser, et al., 1997). Therefore, another question that warranted research is whether or not sensorimotor grounding facilitates "offline" understanding of discourse. This question was investigated by using open and inference questions (experiments one and two), asking participants to arrange events from the text in the correct order (experiment three) and collecting response times at test (experiments four and five).

Third, a few empirical studies have demonstrated that not only explicit properties of objects are simulated during language processing, but as well implicit properties. As discussed previously, Zwaan et al. (2002) presented participants with the sentences describing an animal whose implied shape changed as a function of its location (e.g., a bird in the sky; a bird in the nest). After reading the sentence, participants were presented with a picture of an animal in question. The researchers found that responses were faster when the animal's shape (i.e., a bird with outstretched wings *vs.* a bird with folded wings) matched the implied shape in the sentence. Therefore, apart from investigating whether participants simulate actions, states and entities mentioned explicitly in the text (experiments one, two, four, and five), this thesis also explored a question whether the comprehenders simulate properties mentioned implicitly. More specifically, this question was investigated in the experiment three in which participants read a text describing an implied left spatial dimension (e.g., driving a car, getting out of a car) and locations (e.g., a heart, a wedding ring).

Fourth, whereas experiments 1 to 3 were aimed at investigating whether simulations capture explicit and implicit information connoted by the language, experiments 4 and 5 constituted an advancement over these studies by investigating whether comprehension of discourse describing metaphorical actions that are physically impossible to perform also requires the construction of a simulation.

Finally, to confirm that deep comprehension indeed requires simulations as some of the supporters of embodied view proposed (e.g., Barsalou et al., 2008), the role of sensorimotor grounding was investigated in more cognitively demanding tasks such as analysis, synthesis, and evaluation (experiments one, two, four, and five). The answers to this question were obtained by asking participants to answer inference questions. A well-known classification of questions into textually explicit and textually implicit (Pearson and Johnson, 1978) was adapted to develop such questions. The textually explicit questions required from participants to judge if the sentence was correct with regard to text's content on the basis of information that came directly from text. The textually implicit questions required from participants to judge if the sentence was correct on the basis of information that was provided in the text, but was not obvious and not directly derivable from the text.

CHAPTER 3

Simulation of Positive Emotions and Discourse Comprehension

Abstract

Recent research has suggested that emotional sentences are understood by constructing an emotion simulation of the events being described. The present study aims to investigate whether emotion simulation is also involved in "online" and "offline" comprehension of larger language segments such as discourse. Participants read a target text describing positive events and were put into different facial postures using the pen manipulation procedure. In Experiment 1 participants in the matching condition read a text while having a pen between their teeth (muscular activation of the smile being facilitated) and participants in the control condition read a text in a normal condition without a pen (muscular activation of the smile being possible, but not facilitated). In Experiment 2 participants in the mismatching condition read a text while having a pen between their lips (muscular activation of the smile being prevented) and participants in the control condition read a text in a normal condition without a pen. "Online" and "offline" processing of text were measured by collecting reading times, testing vividness of imagery, spatial presence, perceived reading ease, and asking to respond to questions checking explicit and implicit comprehension of discourse. The major result was that participants read faster and found it easier to read the target text describing positive emotional events while their bodily systems were prepared for processing of positive emotions rather than unprepared or prevented from positive emotional processing. At the same time, no reading time differences were observed between the participants of control and mismatching conditions, suggesting that interference of processing did not occur when the suggested mood of the text was incongruent with the mood induced by the pen manipulation. Finally, simulation of positive emotions did not have a significant impact on "offline" explicit and implicit discourse comprehension. This suggests that emotion simulation has an impact on "online" comprehension, but may not serve to influence "offline" discourse understanding.

3.1. Introduction

According to some studies, when people adopt certain facial expressions of emotion, they also report emotional feelings that are congruent with their expressions (e.g., Duncan & Laird, 1977; Laird & Crosby, 1974). Recent theories of embodied cognition suggest new ways of conceptualizing emotional processing. These theories propose that knowledge is grounded and demonstrate that emotional processing is also relevant to understanding such core cognitive processes as language comprehension. By “knowledge as grounded” is meant that language processing is achieved via partial simulations of original sensory, motor, and affective states of human body (e.g., Barsalou, 1999a; Barsalou, 1999b; Barsalou, 2008b; Damasio, 1989; de Vega, 2008; Gibbs, 2011; Glenberg & Kaschak, 2002; Glenberg & Robertson, 1999, 2000; Kaschak & Glenberg, 2000; Simmons & Barsalou, 2003; Stanfield & Zwaan, 2001; Zwaan, 1999, 2009). Thus, remembering an emotional event arises from partial simulation of modality-specific states which were initially stored during the original experience. Similarly, understanding information about the emotional event arises from simulation of that original experience (Niedenthal, 2007). This means that body is inextricably linked to the mental process and appears central to the representation of meaning.

Research demonstrates strong evidence in support of action (e.g., de Vega et al., 2004; Hauk et al., 2004; Santana & de Vega, 2013; Zwaan & Taylor, 2006) and perceptual (e.g., Kaschak et al., 2005; Tettamanti et al., 2005) simulation in language comprehension. In contrast, the effect of emotion simulation on language processing has attracted scientific attention only recently. For example, Havas et al. (2007) tested the hypothesis whether reenactment of congruent or incongruent emotions would induce or inhibit sentence comprehension, respectively. In their study participants were asked to read sentences describing emotional or non-emotional events while being in a matching or mismatching emotional state. The results demonstrated that judgment times for sentences describing pleasant events were faster when participants were smiling. Similarly, judgment times for sentences describing unpleasant events were faster when participants were prevented from smiling. In another related study, Havas et al. (2010) provided further evidence to support the claim that emotional bodily feedback plays a casual role in language processing. Participants were injected botulinum toxin-A (BTX) to temporarily paralyze a facial muscle responsible for frowning. Later, they were asked to read sad and angry sentences. The major result was that reading of sad and angry sentences was slowed after Botox injections. This finding is in line with simulation theory which predicts that being prevented from frown makes it more difficult to simulate sadness and anger. The reported data have led experimenters to conclude that emotional bodily states are implicated in such higher cognitive processes as sentence comprehension.

However, there are still a few pending questions that need to be addressed. The first question is about examining the effect of emotion simulation on discourse processing. The existing empirical findings mainly focus on the role of emotion simulation during sentence comprehension and have one important limitation: in everyday life we seldom deal with phrases or sentences used outside the context. Instead, more commonly we are exposed to comprehension of discourse which encompasses such important cognitive functions and processes as memory, perception, and reasoning (Graesser et al., 1997). An increasing number of researchers have pointed that this question has a fundamental bearing on the generalisability of the findings regarding the role of simulation in language processing (see Fischer & Zwaan, 2008, for discussion).

The second question is that most contemporary research on embodied language processing has so far focused on testing how modality-specific simulations influence “online” reading comprehension rather than “offline” reading comprehension. However, language understanding includes both “online” reading (e.g., word decoding, lexical access, syntactic processing) and “offline” postreading processes (e.g., summarization, argumentation, drawing inferences) which invoke different mental representations, and accordingly test different aspects of language comprehension (Graesser et al., 1994; Zwaan & Radvanksy, 1998). In brief, although looking into overall process of comprehension was recurrently stressed (e.g, Goldman & Varma, 1995; Kintsch, 1988; Trabasso & Suh, 1993; van der Broek, Young, Tzeng, & Linderholm, 1999; Zwaan & Singer, 2003), there is an apparent lack of studies about the potential effects of emotional bodily states on “offline” language comprehension.

Nonetheless, there are good reasons to think that emotion simulation could facilitate “offline” language comprehension. First, according to Language and

Situated Simulation Theory (LASS) put forward by Barsalou et al. (2008) a simulation system represents deeper conceptual processing compared to a linguistic system. In particular, this theory suggests that at the onset of language processing the linguistic system gets activated immediately and serves to recognize the words and produce associated linguistic forms (e.g., “computer” is associated with “mouse”, “keyboard”, etc.). The associations between the words are sufficient for shallow comprehension tasks. Later, the different meanings of the given word are simulated in the modality-specific systems to allow the comprehender to disambiguate the meaning of the word and identify the most relevant perceptual, action, and introspective elements. At this stage, the comprehender engages in a deeper conceptual processing compared to the purely linguistic processing. Therefore, when linguistic processing dominates, people tend to build shallow meaningful representations derived from information explicitly provided in the text. Conversely, when simulation system dominates, people tend to build comprehensive mental representations from inferences (information that goes beyond words mentioned in the text) computed during processing of discourse. Second, research suggested that imagery plays important roles in better recall of information (e.g., Bower & Winzenz, 1970; Paivio, 1971) and that simulation affects both imagery and perception during conceptual processing (Barsalou et al., 1999). The strong case for the role of imagery in simulation is presented by the recent work of Wu and Barsalou (2009) which showed that people use mental images during simulation of occluded internal and external properties of nouns and noun phrases that refer to objects. For example, participants reported higher accessibility to such internal properties as “seeds” or “red” while being asked to list characteristics of “half watermelon” than “watermelon”. Third, the most recent work on early reading comprehension demonstrated that embodied interventions help children better remember parts of texts and answer inference questions (Glenberg, 2011; Glenberg et al., 2011; Glenberg, Jaworski, Rischal, & Levin, 2007). Finally, convincing arguments about the central role of simulation in offline language comprehension can be found in the research of Pecher et al. (2009). More precisely, in this study participants were instructed to read a list of sentences describing objects and then to perform surprise recognition memory task on the pictures. The researchers found that recognition performance was better if the picture matched the implied shape or orientation of the object in an earlier sentence. An effect of match was found both when participants responded immediately after reading the sentences and when sentence reading and picture recognition were separated in time (45-min delay).

To conclude, a growing body of research shows that comprehension of emotional sentences requires the involvement of bodily systems to simulate the situation described by the sentence. The present study extends this research in two ways. First, whereas most previous studies used sentence stimuli, this research focused on extended linguistic events (texts). Second, both online (self-paced reading times) and offline (verbatim and inference questions) measures of comprehension were taken.

3.2. Hypotheses and overview of the experiments

Experiment 1 assessed whether congruent emotional bodily states might potentially facilitate “online” and “offline” comprehension of discourse. It was expected that participants should read a text about happy relationship faster while being in the matching condition (i.e., muscular activation of smile being facilitated) rather than in the control condition (i.e., while reading naturally). With regard to “offline” processing, it was expected that participants who belong to a matching condition would retrieve both explicitly presented material and inferential material implied in the text better than participants in the control condition.

Experiment 2 assessed whether incongruent emotional bodily states might potentially impair “online” and “offline” discourse processing. It was expected that participants should read a text about happy relationship slower while being in the mismatching condition (i.e., muscular activation of smile being prevented) rather than in the control condition (i.e., while reading naturally). Additionally, it was expected that participants in the mismatching condition would find it more difficult to read a text than participants in the control condition (this hypothesis was tested with the questionnaire items measuring perceived reading ease). These predictions are in line with a strong embodiment claim which suggests that if systems of the body are in inappropriate emotional states, then these states should interfere with language processing (see Glenberg, Havas, Becker, & Rinck, 2005, for discussion). Finally, it was hypothesized that participants in the mismatching condition would integrate both explicitly presented material and inferential material implied in the text worse than participants in the control condition.

To test these hypotheses, in both experiments participants were asked to read an emotionally neutral tutorial text about the protagonist’s life on a Faial Portuguese Island of the Azores. The text contained a lot of factual and descriptive information, and thus did not promote any kind of positive emotional processing. Reading times were collected and served as a study baseline for the rest of the experiment to control for individual differences in reading speed. Second, participants were timed on how much time they spent reading the target text that described emotionally positive events (i.e., romantic relationship of a couple).

In Experiment 1 participants in the matching condition read the text while holding the pen sideways between the teeth to force a partial smile (Oberman, Winkielman, & Ramachandran, 2007), and, accordingly, boost “online” and “offline” discourse comprehension. Participants in the control condition read the text naturally without any manipulation with a pen.

In Experiment 2 participants in the mismatching condition read the text while holding the pen straight between the lips, without touching the pen with their teeth, to prevent smile, and, accordingly, impair “online” and “offline” processing of discourse (Oberman et al., 2007; Strack, Martin, & Stepper, 1988). Participants in the control condition read the text naturally without any manipulation with a pen. Pictorial information on how facial expressions have been manipulated in both experiments is given in Figure 3.1.

After reading the target text, participants in both experiments were asked to fill in a paper-based questionnaire that assessed their mental imagery, spatial presence, perceived reading ease, and “offline” explicit and implicit comprehension of the events described in the target text. In the end of the experiment participants were interviewed what they thought about the pen manipulation procedure.

Figure 3.1. Different ways in which facial expressions relative to smiling and frown have been manipulated in Experiments 1 and 2. From left to right, the author demonstrates how participants read the text describing positive events while having a pen between their teeth (muscular activation of the smile being facilitated), having a pen between their lips (muscular activation of the smile being prevented), or in a normal condition without a pen (muscular activation of the smile or frown being possible, but not facilitated).

3.3. Experiment 1

An embodied approach to language processing suggests that understanding of emotional language requires the partial reenactment of emotional bodily states. Consequently, if bodily systems are prepared for processing of congruent emotions, then language comprehension should be facilitated. With regard to “online” processing, it was expected that comprehension would be facilitated when the suggested mood of the text is congruent with the emotional state induced by the pen manipulation. That is, participants should read a text about happy relationship faster while having a pen between their teeth (matching condition) than in a normal condition without a pen (control condition). With regard to “offline” processing, it was expected that details of emotion simulation would be retained after reading is completed. That is, participants who belong to a matching condition should retrieve both explicitly presented material and inferential material implied in the text better than participants from the control condition.

3.3.1. Method

3.3.1.1. Participants

A total of 40 Portuguese citizens (M_{age} = 26.50, SD_{age} = 8.24) participated in the experiment: 16 participants were male (M_{age} = 28.75; SD_{age} = 10.58), 23 were female (M_{age} = 24.78; SD_{age} = 6.05), one participant did not indicate gender. Everyone who took part in the study received a copybook in exchange for participation.

3.3.1.2. Design and materials

The experiment was a single factor between-participants design. Participants were randomly assigned to one of the two aforementioned facial posture conditions: pencil in the teeth (consistent with the valence of the narrative) and no pencil (control condition).

The materials consisted of two texts (tutorial and target) and a questionnaire. The tutorial text was neutral and the target text described emotionally positive events. Both texts were constructed to have eight paragraphs of exactly the same size. That is, the size of paragraphs in the tutorial text matched the size of paragraphs in the target text (e.g., paragraph one in both texts had 464 characters including spaces). Importantly, each paragraph of the target text described an emotional episode. Approximate English translation of the complete versions of tutorial and target text is given in Table 3.1 and Table 3.2, respectively. Portuguese original versions of tutorial and target texts are given in Annex C and Annex D, respectively.

Table 3.1

Approximate English Translation of the Tutorial Text Used in Experiment 1

1	It was almost summer. To be more precise, it was the end of May. I didn't even have to go there. I was only supposed to go to Faial to present my book. However, something strange happened at the market in Lisbon. While I was giving autographs to fans, I noticed a girl who was looking at me. Suddenly, she approached me and said, "I'd like to use an opportunity before you begin the presentation. My name is Maria".
2	We start walking together. We made a deal that we would not go by the end of the road, but stop in the middle of the road and sit on the lava rock nearby, whose shape reminds visitors of human body.
3	Everyone can choose his own lava rock. Here the wind is not very strong as well as the noise of the sea. Sometimes the noise of the wind absorbs the noise of the sea, as a result of which you can see the sea, but cannot hear it. The wind and the sun are similar to flames of fire.
4	At night the weather gets slightly fresher. The earth, however, is still warm and is emitting lots of heat. If you step on it, you can feel how the warmth is reaching your knees, making you feel as if you were in the middle of a bonfire. You can feel the "breathing sun" only after walking a few seconds along the highway 21.
5	In the distance one can see the first lights of Madalena. Just a few lights, the first illumination of the principal village. The bar on the square is still opened as well as the restaurant with no one inside. At this season of the year one can meet a few tourists, fortunately, only a few tourists.
6	I sound as if I have never been a tourist. I am leaving, so why should I bother who comes here? An old habit wanting to know everything, even when you are far away. Wherever I go I wonder if locals do the same as tourists like to do. I really think that they don't, that there are two different and parallel lives, and that what tourists do is unknown for those living in the same place. So wherever I go I never try to do what tourists usually do, since otherwise it would seem as if I had never been to that place.
7	It is getting very late. The day is starting to get heavy and I start getting tired. Why do I feel so? I have no idea what made me come here. Memories, memories are really strange, very strange. I always have a feeling that if I could get back and relive that memory, I would have discovered something different from what I remember now.
8	The features of present life. You add them when you cannot remember the memory. They change it to the extent that you end up remembering something different, something shaped by your life. Memories, memories, memories…

Table 3.2

Approximate English Translation of the Target Text Used in Experiment 1

1	An 81-year-old Finnish man has married a 54 year-old Finnish woman he met online, proving that love conquers everything. Jan-Erik Enestam, who is best known for his book “Love comes with age”, says that “The Internet does not belong only to the youth. There are no rules against old people seeking love online,” said the happy retired lawyer who has been using internet for 10 years already.
2	The bride’s parents, aged 76 and 72, were not very happy about their daughter’s choice for a husband because of the man’s poor eyesight and, of course, age. However, the happiness of their daughter and the constant smile on her face made them accept Jan-Erik to their family.
3	When asked why she has chosen Jan-Erik as a future husband, Mikko Koskinen said, “Well, his voice seemed to me very youthful and I found him an extremely kind man”.
4	“After 8 months in marriage, my 81 year-old husband still makes things which my previous four husbands never did to me. For instance, he always brings coffee into my bed, buys my favorite flowers, and sometimes even organizes romantic suppers with candles”, said Mikko with the wide smile on her face.
5	One day the couple decided to leave the snow-filled streets of Finnish capital for a vacation in Egypt to mark the first anniversary of their marriage. Since man’s wife was a realtor and had a very tight schedule, they both decided that the husband would fly first and the wife would meet him there the next day. And so it happened.
6	When the man’s plane landed in Cairo, the first thing he saw on leaving the plane were vast surges and clouds of red sand raising and rolling forward like giant waves. The temperature left an impression of being in a grill, especially for the man who spent all his life in snowy Finland. But despite the climate, man’s impressions of Egypt were all but positive. On the bus which drove the man to the hotel, Jan-Eric had an opportunity to enjoy the most beautiful sites he ever saw in his life: the shadows of Great Pyramids, the Valley of the Kings and the temple of Abu Simbel.
7	Having reached the hotel, he decided to send his wife a quick email. Unfortunately, while typing her address, he missed one letter, and his note was directed instead to an elderly preacher’s wife whose 67 year-old husband had passed away only the day before. When the grieving widow decided to check her email, she took one look at the monitor, let out a piercing scream and fell to the floor losing consciousness.
8	Having heard the sound, her family rushed into the room and saw this note on the screen: My Dearest Wife, Just got checked in. Everything is prepared for your arrival tomorrow. Keep in my mind it is unbearably hot down here.

3.3.1.2.1. Measures of "online" discourse comprehension

Collection of reading times

Reading times were collected for whole paragraphs as readers normally read the text.

Completion of questionnaire

Participants were asked to fill in the questionnaire that measured perceived reading ease, vividness of mental imagery, and feeling of spatial presence immediately after reading the text. The decision to measure the degree of mental imagery and feeling of presence was guided by previous research and theory that placed emphasis on the role of imagery and situated nature of concepts in language comprehension (Barsalou, 2008b; Barsalou et al., 2008; Spivey & Geng, 2001).

- *Perceived reading ease*

Perceived reading ease was measured on a 7-point scale ranging from (1) *completely disagree* to (7) *completely agree*. The items used in the scale are presented in Table 3.3 (see Annex E for a Portuguese version).

Table 3.3

The Items Used to Measure Perceived Reading Ease in Experiment 1

	Totally disagree						**Totally agree**
I did not find any difficulties understanding the details of the text	1	2	3	4	5	6	7
I found the reading process of the text easy	1	2	3	4	5	6	7

- *Vividness of mental imagery*

To test the vividness of mental imagery, VVIQ Scale of Marks (1973) was adapted, where participants were asked to rate their tendency to mental imagery while reading the target text on a 7-point semantic differential scale. A scale is presented in Table 3.4 (see Annex E for a Portuguese version of a scale).

Table 3.4

A Scale of Vividness of Mental Imagery Used in Experiment 1

Task: When I was reading the text, the image of the presentation in my mind was:

Vivid	1	2	3	4	5	6	7	Vague
Clear	1	2	3	4	5	6	7	Unclear
Indistinct	1	2	3	4	5	6	7	Distinct
Sharp	1	2	3	4	5	6	7	Dull
Intense	1	2	3	4	5	6	7	Weak
Lifelike	1	2	3	4	5	6	7	Lifeless
Fuzzy	1	2	3	4	5	6	7	Unambiguous

- *Spatial presence*

To test the feeling of presence, the subscale of Self Location of the Spatial Presence Scale (Vorderer et al., 2004) was applied. It is a seven-item instrument aimed at assessing participants' feeling of self-location in a virtual world. Participants had to rate their illusory self-location on a 7-point scale, ranging from (1) *completely disagree* to (7) *completely agree*. A subscale is presented in Table 3.5 (see Annex E for a Portuguese version of a subscale).

Table 3.5

A Subscale of Spatial Presence Used in Experiment 1

Task: When I was reading the text, I had a feeling that:

	Totally disagree						**Totally agree**
I was in the middle of the action described in the text rather than just merely observing	1	2	3	4	5	6	7
I was part of the environment described in the text	1	2	3	4	5	6	7
I was actually there in the environment of the presentation	1	2	3	4	5	6	7
The objects in the presentation surrounded me	1	2	3	4	5	6	7
My true location shifted in the environment of the presentation	1	2	3	4	5	6	7
I was physically present in the environment of the presentation	1	2	3	4	5	6	7
I actually took part in the environment of the presentation	1	2	3	4	5	6	7

3.3.1.2.2. Measures of "offline" discourse comprehension

To measure "offline" explicit and implicit comprehension of discourse, the types of questions used in standardized reading assessments were created (see Alderson, 2000; Hughes, 2003, for discussion). Importantly, "offline" comprehension questions were preceded by 43 questions that referred to "online" and control reading measures, and thus were not answered immediately after reading the text.

- *Explicit comprehension*

To measure explicit comprehension, participants were asked to answer to 10 open-ended questions about information explicitly given in the target text. All the questions used in the experiment are presented in Table 3.6 (see Annex F for a Portuguese version). A performance indicator was the mean number of correct answers.

Table 3.6

The Questions Used to Test Explicit Comprehension of Discourse in Experiment 1

1. What is the gap in age between a man and a woman?
2. For how many years has the man been using the Internet?
3. What health problem does the man have?
4. From what country do the man and the woman come from?
5. What is the profession of the woman?
6. Whom did the man send an email?
7. What was the profession of the man?
8. How did the couple meet?
9. Why did the couple decide to go to Cairo?
10. What time of the year was in the city when the couple decided to go to Cairo?

- *Implicit comprehension*

To measure implicit comprehension, participants were asked to rate on a 7-point scale from (1) *completely disagree* to (7) *completely agree* their level of agreement with 15 statements based on implicit guessing. The answers to implicit questions are not as easy as to explicit questions, considering that they require from participants to make reasoned judgments to assess the validity of statements (Person & Johnson, 1980). For example, according to the text, the man gives flowers to his wife every day, and thus it can easily be inferred that a statement such as "The couple is in a romantic relationship" is true. The scores were averaged, creating a mean score of participants' comprehension performance in each condition. In short, the higher the mean score, the better the implicit comprehension of participants. The statements used to assess implicit comprehension are given in Table 3.7 (see Annex F for a Portuguese version).

Table 3.7

The Statements Used to Assess Implicit Comprehension of Discourse in Experiment 1

	Totally disagree						**Totally agree**
1. The husband is happy in marriage	1	2	3	4	5	6	7
2. The wife is happy in marriage	1	2	3	4	5	6	7
3. The husband is currently unemployed	1	2	3	4	5	6	7
4. The couple lives in the city with a population of more than 50.000 people	1	2	3	4	5	6	7
5. The relationship of the couple is romantic	1	2	3	4	5	6	7
6. The weather in Cairo was windy when the man arrived	1	2	3	4	5	6	7
7. The temperature in Cairo was above 30 º C	1	2	3	4	5	6	7
8. While going in the bus to the hotel, the man saw many historical sites	1	2	3	4	5	6	7
9. The man mistyped the email address of his wife because of poor eyesight	1	2	3	4	5	6	7
10. The wife of the man was married before	1	2	3	4	5	6	7
11. The man was seeking love online for more than a year	1	2	3	4	5	6	7
12. It was difficult for parents of the bride to give agreement for marriage	1	2	3	4	5	6	7
13. The husband is a humorous type of man	1	2	3	4	5	6	7
14. The husband is fond of history	1	2	3	4	5	6	7
15. The couple is enjoying their happiness	1	2	3	4	5	6	7

3.3.1.2.3. Control variables

Studies in social cognition demonstrated that transient moods (or incidental moods) can have a deep impact on information processing and social evaluation. In particular, negative moods were shown to elicit central, systematic, and step-by-step information processing, whereas positive moods were shown to trigger heuristic, peripheral, and shallow information processing (Chaiken, Pomerantz, & Giner-Sorolla, 1995; Petty & Cacioppo, 1986; Schwarz, 1990, 2002). Transient moods were also shown to be misattributed and (mis)interpreted as a reaction to the social target and to produce social judgments that are congruent in valence with the mood (i.e., mood as information hypothesis; Clore, Schwarz, & Conway, 1990). In order to rule out the possibility that the pen procedure could produce a transient mood state that could interfere with the manipulation of embodiment, the perceived attention grabbing and reading satisfaction were measured on a 7-point scale ranging from (1) *completely disagree* to (7) *completely agree*. Additionally, the social evaluation of the protagonist was assessed with a 7-point semantic differential scale (see Tables 3.8-3.10 for the items used; see Annex G for a Portuguese version). Because all of the scales had high reliabilities (Chronbach's alpha for each measure is reported in the section "Results"), the mean was calculated for each of the control measures and the subsequent statistical analyses were performed on the mean scores of participants in the two conditions.

Table 3.8

The Items Used to Assess the Perceived Attention Grabbing in Experiment 1

	Totally disagree						**Totally agree**
1. The text is holding attention	1	2	3	4	5	6	7
2. The text is engrossing	1	2	3	4	5	6	7
3. The text is intriguing	1	2	3	4	5	6	7

Table 3.9

The Items Used to Assess Reading Satisfaction in Experiment 1

	Totally disagree						**Totally agree**
1. My level of satisfaction with the text is high	1	2	3	4	5	6	7
2. I found the reading process of the text enjoyable	1	2	3	4	5	6	7
3. Having finished reading the text, I felt as if I could not stop smiling	1	2	3	4	5	6	7
4. In the future I would eagerly read another story of such type	1	2	3	4	5	6	7

Table 3.10

The Items Used to Assess Social Evaluation of the Protagonist in Experiment 1

enthusiastic	1	2	3	4	5	6	7	unenthusiastic
playful	1	2	3	4	5	6	7	unplayful
youthful	1	2	3	4	5	6	7	elderly
joyful	1	2	3	4	5	6	7	sorrowful
cheerful	1	2	3	4	5	6	7	depressed
passionate	1	2	3	4	5	6	7	passionless
lucky	1	2	3	4	5	6	7	unfortunate
energetic	1	2	3	4	5	6	7	lethargetic
optimistic	1	2	3	4	5	6	7	pessimistic
lively	1	2	3	4	5	6	7	dull
blissful	1	2	3	4	5	6	7	unhappy
flattering	1	2	3	4	5	6	7	unflattering

3.3.1.3. Procedure

Participants were contacted directly by the experimenter at university campus and were asked to participate in the experiment aimed at assessing reading comprehension. Everyone was informed about the confidentiality and anonymity of the data, and the possibility to quit the study at any time. Participants were tested individually in a quiet sound insulated room. They sat in a comfortable chair and were told that the experiment would consist of three parts: reading of the tutorial text on a computer, reading of the target text on a computer, and filling in of the paper-based text-related questionnaire.

For the first part of study all participants were instructed to read an emotionally neutral text from a laptop computer screen (Model HP G62; screen resolution – 1366×768) under the pretext of having a tutorial session for the computer-based part of experiment. Everyone was informed that each paragraph of the text would be displayed separately on a computer screen and that moving to the next paragraph would require pressing the “Space” key. Participants were also told that their reading performance would be timed, and that they should press the “Space” key as quickly as possible while still maintaining accuracy (Fazio, 1990). Reading times were collected using Stimuli Presentation Software (Version 0.50).

For the second part of study participants were instructed to read the target text describing emotionally positive events and were randomly assigned to one of the experimental groups. Participants in the matching condition read the text with the pen sideways between their teeth (i.e., inducing smile). Participants in the control condition read the text naturally without any manipulation with a pen. Reading procedure was identical to that of the tutorial text. When participants finished reading the target text, they were told to remove a pen from the mouth and were instructed to fill in the text-related paper-based questionnaire. Finally, in post-experimental interview participants were asked what they thought about the pen manipulation procedure to remove the data from those who would answer in the affirmative. This interview was important for the study as social psychology literature (e.g., Laird, 1974) suggests that participants who are aware of emotion manipulation tend to regulate their responses more effectively, and thus can bias the results.

3.3.2. Results

3.3.2.1. Control variables

To rule out the possibility that the pen procedure could elicit any specific information processing (i.e., heuristic or systematic processing) or any misattribution of mood, an independent-samples t-test was conducted on attention grabbing (Chronbach's alpha = .81), reading satisfaction (Chronbach's alpha = .87), and social evaluation of the main character (Chronbach's alpha = .80) to assess the difference in scores between participants of matching and control conditions. The results revealed that participants in the matching condition (*M* = 4.24; *SD* = 1.34) did not differ significantly in their responses from participants in the control condition (*M* = 4.31; *SD* = 1.14) regarding the attention grabbing measure, t (38) = -0.19, p >.10. Similarly, participants in the matching condition (*M* = 5.01; *SD* = 1.05) did not differ significantly in their responses from participants in the control condition (*M* = 5.00; *SD* = 1.70) regarding the reading satisfaction measure, t (38) = 0.03, p >.10. Finally, there were no significant differences in responding between the participants of the matching condition (*M* = 4.10; *SD* = 1.05) and control condition (*M* = 4.42; *SD* = 0.82) with regard to social evaluation of the main character, t (38) = -1.08, p >.10. Follow-up analyses showed that there was no significant effect of gender on target text reading time after controlling for the effect of tutorial reading time, F (1, 36) = 0.54, $p > .05$. Similarly, by classifying age into the three groups (18-29, 30-49, 50+), it was revealed that there was no significant effect of age on target text reading time after controlling for the effect of tutorial reading time, F (2, 36) = 0.07, $p > .05$. Finally, a post-experimental interview confirmed that none of the participants was aware of emotion manipulation.

3.3.2.2. "Online" comprehension measures

Target text reading time. An 8 (Paragraphs 1 to 8) within factor x 2 (condition: matching *vs.* control) between factor mixed ANOVA, with tutorial reading time as a covariate, was conducted to analyze the reading times of the target text. Because tutorial and target texts were identical in size, tutorial reading time was chosen as a covariate in order to control for individual differences in reading speed.

The results showed that tutorial reading time (reported in milliseconds) was significantly related to the participant's target text reading time, F (1, 37) = 400.92, $p < .001$, partial $\eta^2 = .92$. There was also a significant effect of pen condition on target text reading time after controlling for the effect of the tutorial reading time, F (1, 37) = 21.97, $p < .001$, partial $\eta^2 = .37$. Planned contrasts revealed that participants in the matching condition read the target text faster (M = 14974.39; SE = 288. 68) than participants in the control condition (M = 16888.64; SE = 288.68), t (37) = -4.69, $p <$ .001, r = .61.

Finally, using a Pillai's trace, it was revealed that there was a significant effect of pen condition on the speed with which participants read paragraphs of text, F (8, 30) = 3.31, p = .008. Planned contrasts demonstrated that participants in the matching condition processed the target text significantly faster than participants in the control condition while reading the paragraphs one, two, three, five, six, and seven (see Figure 3.2 and Table 3.11). For the mean differences and exact p-values, see Table 3.12.

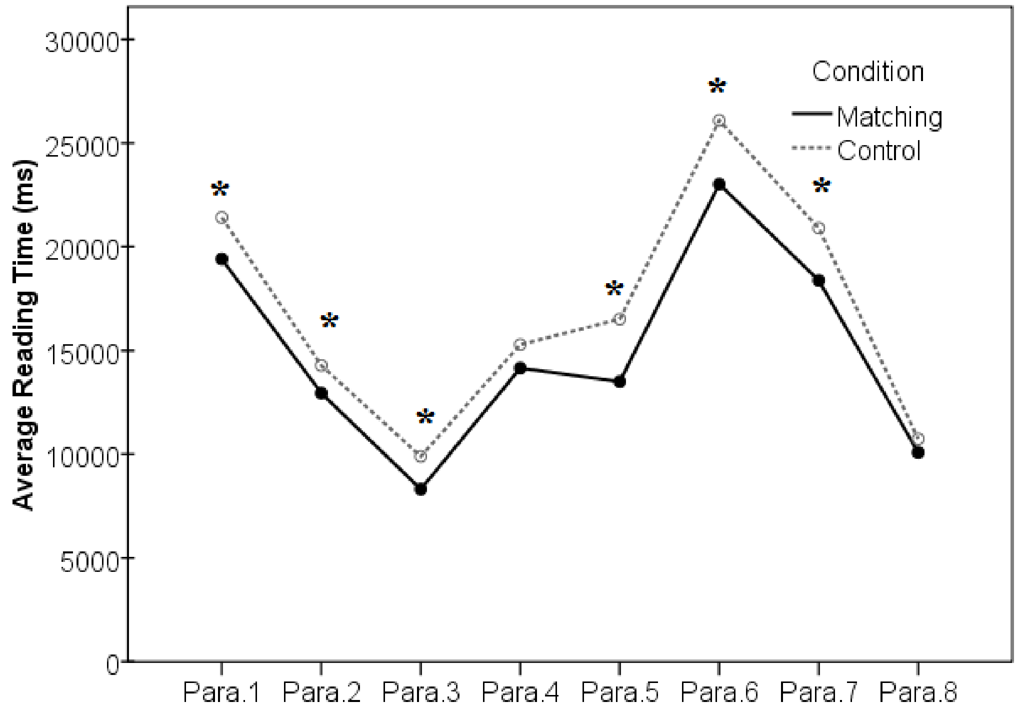

Figure 3.2. Mean reading times in milliseconds (estimated marginal means) for eight paragraphs of the target text according to condition (matching *vs.* control) in Experiment 1. *Note:* asterisks refer to significant pairwise comparisons ($p < .05$).

Table 3.11

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 1

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Matching	19408.81[a]	484.60	18426.93	20390.70
	Control	21411.99[a]	484.60	20430.10	22393.87
2	Matching	12943.96[a]	328.08	12279.22	13608.71
	Control	14279.07[a]	328.08	13614.33	14943.81
3	Matching	8311.61[a]	392.62	7516.09	9107.13
	Control	9893.72[a]	392.62	9098.20	10689.24
4	Matching	14150.93	398.91	13342.66	14959.21
	Control	15285.54	398.91	14477.26	16093.81
5	Matching	13499.24[a]	546.57	12391.78	14606.70
	Control	16515.10[a]	546.57	15407.63	17622.56
6	Matching	23021.76[a]	675.59	21652.88	24390.63
	Control	26091.40[a]	675.59	24722.53	27460.28
7	Matching	18376.76[a]	600.86	17159.30	19594.22
	Control	20896.81[a]	600.86	19679.35	22114.27
8	Matching	10082.08	400.65	9270.30	10893.87
	Control	10735.51	400.65	9923.72	11547.29

Note: Means sharing letter "a" within the same paragraph differ significantly at $p < .05$.

Perceived ease of reading (Chronbach's alpha = .92). On average, participants in the matching condition ($M = 5.78$; $SD = 1.41$) and control condition ($M = 5.90$; $SD = 1.32$) found the text equally easy to read, $t\ (38) = -0.28$, $p > .05$.

Feelings of presence (Chronbach's alpha = .86). On average, participants felt equally present in the matching condition ($M = 3.63$; $SD = 1.15$) and control condition ($M = 3.15$; $SD = 1.35$), $t\ (38) = 1.23$, $p > .05$.

Vividness of mental imagery (Chronbach's alpha = .83). On average, participants did not significantly differ in their answers in the matching condition ($M = 4.41$; $SD = 1.12$) and control condition ($M = 4.33$. $SD = 0.74$), $t\ (38) = 0.26$, $p > .05$.

Table 3.12

Pairwise Comparisons of Mean Reading Times in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 1

Para.	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
1	Matching	Control	-2003.18	685.52	.006	-3392.16	-614.19
	Control	Matching	2003.18	685.52	.006	614.19	3392.16
2	Matching	Control	-1335.1	464.10	.007	-2275.47	-394.76
	Control	Matching	1335.11	464.10	.007	394.76	2275.47
3	Matching	Control	-1582.11	555.40	.007	-2707.46	-456.76
	Control	Matching	1582.11	555.40	.007	456.76	2707.46
4	Matching	Control	-1134.60	564.31	.052	-2278.00	8.79
	Control	Matching	1134.60	564.31	.052	-8.79	2278.00
5	Matching	Control	-3015.85	773.19	.000	-4582.48	-1449.23
	Control	Matching	3015.85	773.19	.000	1449.23	4582.48
6	Matching	Control	-3069.65	955.70	.003	-5006.07	-1133.22
	Control	Matching	3069.65	955.70	.003	1133.22	5006.07
7	Matching	Control	-2520.05	849.98	.005	-4242.28	-797.82
	Control	Matching	2520.05	849.98	.005	797.82	4242.28
8	Matching	Control	-653.43	566.76	.256	-1801.79	494.94
	Control	Matching	653.43	566.76	.256	-494.94	1801.79

3.3.2.3. "Offline" comprehension measures

Explicit comprehension. An independent-samples t-test on the number of correct answers to open questions indicated that participants' performance was not significantly different in the matching (M = 3.88; SD = 1.41) and control (M = 4.82; SD = 1.60) conditions, t (31) = -1.81, p > .05.

Implicit comprehension (Cronbach's alpha = .75). On average, participants did not differ significantly in their answers to 15 implicit questions in the matching (M = 5.32; SD = 0.80) and control (M = 5.41; SD = 0.86) conditions, t (38) = - 0.36, p > .05.

3.3.3. Discussion

The present experiment assessed whether getting bodily systems into a congruent emotional state would facilitate "online" and "offline" understanding of discourse. The results showed that participants in the matching condition showed faster reading times relative to participants who performed the task in the control condition. This finding is consistent with previous studies on sentence comprehension that demonstrated better "online" processing of sentences when emotional state matched sentence valence (e.g., Glenberg et al., 2005; Havas et al., 2007). It is important to note that the increased reading speeds in the matching condition were not accompanied by poorer comprehension in "offline" comprehension measures, and thus cannot be attributed to a speed-accuracy tradeoff. At the same time, participants in both conditions showed equal performance on measures of "online" processing that involved the participants' metacognitive judgments on their own comprehension processes (i.e., perceived ease of reading, vividness of mental imagery, spatial presence) and measures of "offline" discourse processing. Thus, it can be concluded that emotion simulation had an impact on "online", but not "offline" discourse comprehension.

3.4. Experiment 2

A strong embodiment stance suggests that if emotional bodily states are incongruent with emotional valence of the text, then these states should interfere with language processing (e.g., Glenberg et al., 2005). Experiment 2 was designed to test this prediction. More specifically, it assessed whether an incongruent emotional bodily state would impair "online" and "offline" discourse processing.

3.4.1. Method

3.4.1.1. Participants

A total of 40 Portuguese citizens (M_{age} = 26.20, SD_{age} = 7.43) participated in the experiment: 17 participants were male (M_{age} = 27.65; SD_{age} = 9.73), 21 were female (M_{age} = 25.14; SD_{age} = 5.11), two participants did not indicate gender. Everyone who took part in the study received a copybook in exchange for participation.

3.4.1.2. Design and Materials

Design and materials were strictly identical to those for Experiment 1.

3.4.1.3. Procedure

The procedure was identical to that for Experiment 1, with the exception that participants read the target text in either control (no manipulation with a pen) or mismatching (with the pen straight between the lips to facilitate muscular activation of frown) condition.

3.4.2. Results

3.4.2.1. Control variables

To rule out the possibility that the pen procedure could elicit any specific information processing (i.e., heuristic or systematic processing) or any misattribution of mood, an independent-samples t-test was conducted on attention grabbing (Chronbach's alpha = .60), reading satisfaction (Chronbach's alpha = .85) and social evaluation of the main character (Chronbach's alpha = .79) to assess the difference in scores between the participants of control and mismatching conditions. The results revealed that participants in the control condition (M = 4.25; SD = 1.12) did not differ significantly in their responses from participants in the mismatching condition (M = 4.47; SD = 1.17) regarding the attention grabbing measure, t (38) = -0.60, p >.10. Similarly, participants in the control condition (M = 5.13; SD = 1.51) did not differ significantly in their responses from participants in the mismatching condition (M = 4.47; SD = 1.17) regarding the reading satisfaction measure, t (38) = 0.84, p >.10. Finally, there were no significant differences in responding between the participants of the control condition (M = 4.32; SD = 0.72) and mismatching condition (M = 4.34; SD = 1.09) with regard to social evaluation of the main character, t (38) = -0.07, p >.10. Follow-up analyses showed that there was no significant effect of gender on target text reading time after controlling for the effect of tutorial reading time, F (1, 35) = 0.09, p > .05. Similarly, by classifying age into the three groups (18-29, 30-49, 50+) it was revealed that there wasn't a significant effect of age on target text reading time after the controlling for the effect of tutorial reading time, F (2, 36) = 0.21, p > .05. Finally, a post-experimental interview confirmed that none of the participants was aware of emotion manipulation.

3.4.2.2. "Online" comprehension measures

Target text reading time. An 8 (Paragraphs 1 to 8) within factor x 2 (condition: control *vs.* mismatching) between factor mixed ANOVA, with tutorial reading time as a covariate, was conducted to analyze the reading times of the target text. The results showed that the covariate, tutorial reading time, was significantly related to the participant's target text reading time, F (1, 37) = 261.47, $p < .001$, partial $\eta^2 = .86$. However, there was no effect of pen condition on target text reading time after controlling for the effect of the tutorial reading time, F (1, 37) = 0.34, $p >$ .05. Considering that the one-way analysis of variance (ANOVA) is not significant, and therefore does not protect against inflated Type I error rates in subsequent analyses of data, planned contrasts are not reported (see Howell, 2006, for further discussion). Estimated marginal reading time means of participants from both conditions are provided in Table 3.13.

Table 3.13

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 2

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Mismatching	19001.67	464.79	18059.93	19943.42
Control	18607.71	464.79	17665.97	19549.46

Finally, using Pillai's trace, it was revealed that there was no significant effect of pen condition on the speed with which participants read paragraphs of text, F (8, 30) = 1.21, $p > .05$. Considering that the multivariate analysis of variance (MANOVA) is not significant, and therefore does not protect against inflated Type I error rates in follow-up a-priori comparisons, planned contrasts are not reported (see Bock, 1975, for further discussion). At the same time, a non-significant MANOVA does not allow to fully understand how comprehension proceeded throughout the text. Furthermore, it can be argued that a non-significant MANOVA may ignore nearly significant differences (for some of the dependant variables) which are theoretically interesting for the present research. To resolve this issue, MANOVA was followed with separate ANOVAs on each of the dependent variables. To control for the inflation of familywise error rate by conducting more tests on the same data, a Bonferroni correction was applied to the subsequent ANOVAs (see Harris, 1975, for further discussion). The results of univariate test statistics, however, revealed that participants did not significantly differ, nor approached significance in their reading of each of the paragraphs of the target text (see Figure 3.3 and Table 3.14). For the mean differences and exact *p*-values, see Table 3.15.

Perceived ease of reading (Cronbach's alpha = .94). On average, participants in the control condition found the text significantly easier to read (M = 5.78; SD = 1.38) than participants in the mismatching condition (M = 4.05; SD = 2.20), t (38) = 2.97, p <.001, r = .43.

Feelings of presence (Cronbach's alpha = .97). On average, participants felt equally present in the control condition (M = 3.24; SD = 1.24) and mismatching condition (M = 3.88; SD = 1.53), t (38) = - 1.41, p > .05.

Vividness of mental imagery (Cronbach's alpha = .80). On average, participants did not significantly differ in their answers in the control condition (M = 4.24; SD = 0.63) and mismatching condition (M = 4.20; SD = 1.10), t (38) = 0.15, p > .05.

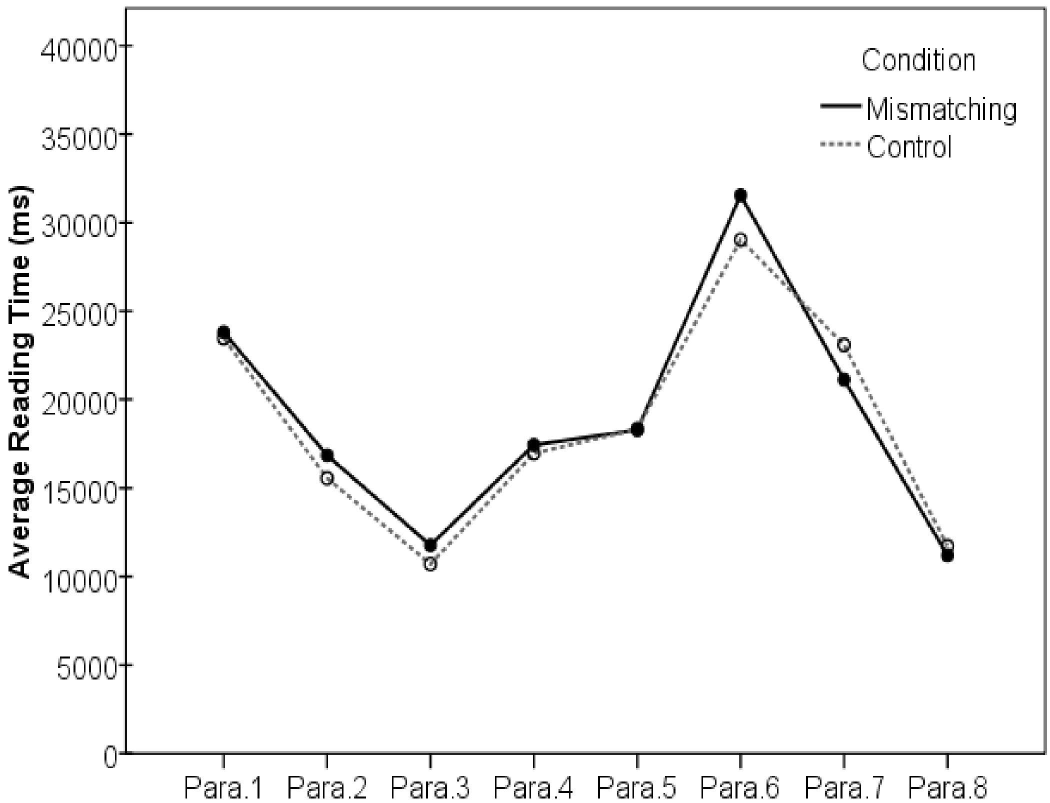

Figure 3.3. Mean reading times in milliseconds (estimated marginal means) for eight paragraphs of the target text according to condition (mismatching *vs.* control) in Experiment 2

Table 3.14

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 2

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Mismatching	23805.86	715.04	22357.06	25254.67
	Control	23469.12	715.04	22020.32	24917.94
2	Mismatching	16851.09	643.92	15546.39	18155.78
	Control	15557.18	643.92	14252.49	16861.88
3	Mismatching	11768.26	522.93	10708.71	12827.81
	Control	10707.17	522.93	9647.62	11766.71
4	Mismatching	17431.98	577.12	16262.61	18601.35
	Control	16961.51	577.12	15792.15	18130.88
5	Mismatching	18285.10	766.96	16731.08	19839.11
	Control	18338.45	766.96	16784.44	19892.47
6	Mismatching	31548.36	1255.44	29004.59	34092.12
	Control	29026.20	1255.44	26482.43	31569.97
7	Mismatching	21122.61	838.04	19424.58	22820.63
	Control	23082.11	838.04	21384.09	24780.13
8	Mismatching	11200.13	568.47	10048.31	12351.95
	Control	11719.10	568.47	10568.14	12871.78

Note: no significant differences in reading speed were found between the participants of mismatching and control conditions for all eight paragraphs of the target text

Table 3.15

Pairwise Comparisons of Mean Reading Times in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 2

Para.	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	Mismatching	Control	336.74	1033.38	.746	-1757.09	2430.57
	Control	Mismatching	-336.74	1033.38	.746	-2430.57	1757.09
2	Mismatching	Control	1293.91	930.59	.173	-591.65	3179.46
	Control	Mismatching	-1293.91	930.59	.173	-3179.46	591.65
3	Mismatching	Control	1061.09	755.74	.169	-470.17	2592.36
	Control	Mismatching	-1061.09	755.74	.169	-2592.36	470.17
4	Mismatching	Control	470.47	834.07	.576	-1219.51	2160.45
	Control	Mismatching	-470.47	834.07	.576	-2160.45	1219.51
5	Mismatching	Control	-53.35	1108.42	.962	-2299.23	2192.52
	Control	Mismatching	53.35	1108.42	.962	-2192.52	2299.23
6	Mismatching	Control	2522.16	1814.38	.173	-1154.12	6198.44
	Control	Mismatching	-2522.16	1814.38	.173	-6198.44	1154.12
7	Mismatching	Control	-1959.51	1211.14	.114	-4413.50	494.49
	Control	Mismatching	1959.51	1211.14	.114	-494.49	4413.50
8	Mismatching	Control	-519.83	821.55	.531	-2184.45	1144.79
	Control	Mismatching	519.83	821.55	.531	-1144.79	2184.45

Note: Letter “a” refers to an adjustment for multiple comparisons: Bonferroni.

3.4.2.3. "Offline" comprehension measures

Explicit comprehension. An independent-samples t-test on the number of correct answers to open questions indicated that participants' performance was not significantly different in the control (M = 4.82; SD = 1.59) and mismatching (M = 4.68; SD = 2.34) conditions, t (34) = 0.21, $p > .05$.

Implicit comprehension. On average, participants did not significantly differ in their answers in the control (M = 5.40; SD = 0.89) and mismatching (M = 4.95; SD = 0.83) conditions, t (37.82) = 1.64, $p > .05$.

3.4.3. Discussion

Experiment 2 was designed to assess whether incongruent emotional bodily states impair "online" and "offline" discourse processing. It was found that participants in the mismatching condition did not differ in their "online" and "offline" comprehension performance from the participants in the control condition. At the same time, in line with a strong embodiment claim, participants in the mismatching condition found the text more difficult to read than participants in the control condition, suggesting that it may still be premature to conclusively state that the interference of processing does not occur when the suggested mood of the text is incongruent with the mood induced by the pen manipulation.

3.5. General discussion

The present research was designed to test two major hypotheses derived from an embodied simulation account of language comprehension. Experiment 1 assessed the hypothesis whether congruent emotional states might potentially facilitate "online" and "offline" discourse comprehension. Experiment 2 assessed the hypothesis whether incongruent emotional states might potentially impair "online" and "offline" discourse comprehension.

The results of Experiment 1 showed that manipulation of emotional bodily state through facial posture had an impact on "online" discourse comprehension. More specifically, the results revealed that participants whose bodily systems were prepared for processing of congruent emotions (matching condition) read the target text faster than participants whose bodily systems were not prepared for processing of emotion-congruent information (control condition). The facilitation effect also appeared to be enduring, considering that participants in the matching condition read the target text significantly faster than participants in the control condition while reading paragraphs one, two, three, five, six, and seven. The reported findings are consistent with prior studies on sentence processing that demonstrated better "online" comprehension for sentences when pen condition matched sentence valence (e.g., Havas et al., 2007) and support the idea that embodiment also facilitates "online" comprehension at higher levels than sentences.

The findings reported in Experiment 1 also showed that the effect of emotion manipulation on "online" processing was not uniform across paragraphs, given that congruency effects disappeared at the end of text reading. There are at least two (not necessarily mutually exclusive) possible interpretations for why this happened. First explanation is consistent with LASS Theory of conceptual processing (Barsalou et al., 2008) suggesting that different mixtures of the language and simulation systems might have underlied the comprehension task. Put different, it is possible that superficial linguistic processing was sufficient to support comprehension of certain events, and thus minimal grounding was required. Alternatively, participants' performance could rely heavily on both language and simulation systems, and thus no reading time differences were detected. Another explanation is that participants' musculature fatigued by the end of text reading, as a result of which pen manipulation procedure became unpleasant and interfered with comprehension of text for both matching and mismatching conditions (see Glenberg et al., 2005, for a discussion of the related data including a factor of experiment half).

The results of Experiment 2 showed that the interference of discourse processing did not occur when the suggested mood of the text was incongruent with an emotional state induced by the pen manipulation. Such a conclusion is reached, given that that the findings of Experiment 2 do not show significant reading time differences between control and mismatching conditions. However, two issues call for caution. The first issue concerns the fact that participants in the mismatching condition found the text more difficult to read than participants in the control condition. The second issue is that the mean reading times for paragraphs one to six in the control condition fell in between the mean reading times for the matching and mismatching conditions when two experiments are considered together (see Table 3.5 and Table 3.7, for reading times means). Furthermore, greater differences in reading speed between matching and mismatching conditions relative to matching and control conditions demonstrate a trend that is consistent with an embodied scenario. Therefore, further research is needed before final conclusions can be reached with respect to interference of discourse processing for the mismatching condition.

Interestingly, despite the fact that previous literature suggested that simulation affects both perception and imagery in conceptual processing (Barsalou et al., 1999), the results of the present study demonstrated that participants whose bodily systems were prepared for processing of congruent emotions (matching condition) did not significantly differ on the level of vividness of mental imagery and feeling of presence from participants in the control condition (Experiment 1). Similarly, no differences in responding on the above-mentioned scales were detected in Experiment 2 where control and mismatching groups were compared. There are at least two (not necessarily mutually exclusive) interpretations of the observed non-significance. First, target items of the questionnaire used in the present study assessed imagery effects in comprehension of text in general not taking into account the fact that mental imagery could proceed as a spontaneous and climatic process in reading (see Long, Winograd, & Bridge, 1989, for discussion). Thus, in assessing mental imagery of large language segments such as discourse it might be more valid to ask questions testing vividness of mental imagery for specific events from text and the whole text. Second interpretation is in line with the most recent research on embodied language processing suggesting that participants differ on mental imagery only when performing the tasks typical of specific deeper cognitive processing (processing of visual or spatial information) than is usually needed in default language comprehension (see Louwerse & Jeuniaux, 2008; Louwerse & Jeuniaux, 2010, for discussion). Because the target text of the present study did not promote any cues typical of specific deep cognitive processing, it might be reasonable that no significant effects were obtained for this measure.

Finally, in both experiments no differences were detected between the two groups for “offline” comprehension performance. There are two alternative explanations of null effects. First straightforward interpretation is in line with work of Louwerse (2007) suggesting that deep comprehension does not necessarily require simulations. That is, embodied emotion representations may not serve to build a long-term memory representation of the events in discourse. Another explanation centers on the measures used in the present research. It is possible that such standardized reading assessments as open-ended questions used in the present self-report paper and pencil questionnaire were too demanding for participants, and thus should rather be substituted by other measure.

The study demonstrated a positive effect of congruent emotional states on discourse comprehension. At the same time, the observed results might be interpreted in a different way. For instance, Bower's (1981) theory regarding emotion-cognition interactions makes a similar prediction about comprehension of language. In particular, this theory suggests that emotions are implicated in cognition through the activation of associated nodes that represent words referring to them (e.g., happy node with the words “smile”, “pleasant”, “positive”, etc.). Because these nodes get activated in the initial stage of comprehension, the corresponding words are processed easier throughout the text leading to faster overall reading rate. Under this account, bodily states affect cognition by activating associated nodes, but language comprehension comes from the manipulation of abstract arbitrary symbols. In contrast, simulation theory states that language comprehension is directly grounded in bodily states and does not depend on manipulation of abstract arbitrary symbols. This difference in interpretation between amodal and embodied approaches was investigated by proponents of simulation account of cognition. For example, Havas et al. (2007) used an experimental procedure in their study to rule out the possibility that the interaction effect between manipulation of facial posture and sentence comprehension was accommodated by Bower’s affect priming theory (1981, 1991). More precisely, experimenters constructed pairs of words with two types of prime words (neutral or associated) in order to use the pen manipulation procedure in a lexical decision task. They hypothesized that if amodal explanation of obtained results was correct, then lexical decision would be faster for words preceded by associated primes rather than neutral primes. However, results of the experiment showed no significant effect of the pen manipulation procedure on the speed of responding in a lexical decision task. In brief, although we cannot fully rule out

Bower's explanation of observed effects in our study, we have good reasons to think that emotion simulation was at least partially implicated in comprehension of discourse, given that the pen manipulation procedure we used was identical to that applied in the study of Havas et al. (2007).

Another alternative explanation of present results is provided by subvocalization process (Daneman & Newson, 1992), which makes similar predictions as those proposed in present research with regards to "pen between the teeth condition". The subvocalization is an activation of the phonology when reading silently, and thus it could be argued that opening the mouth during reading (matching condition) might facilitate a phonological activation of the written text, resulting in faster reading. This prediction is supported by work of Hardyck and Petrinovich (1970) who showed that larynx muscles are activated during silent reading and that sub-vocal speech helps comprehension. While such an explanation is theoretically possible, it is highly likely, however, that this is not the case because of the following reason. The subvocalization process would predict that reading of negatively valenced material would be faster in the "pen in the teeth" condition (mouth open) than in the "pen in the lips" condition (mouth closed). However, Havas et al. (2007) reported just the opposite using sentence stimuli. More concretely, the reading times for sentences describing unpleasant situations were faster while participants were in the "pen in the lips" condition than in the "pen in the teeth" condition. Conversely, the reading times for sentences describing pleasant situations were faster while participants were in the "pen in the teeth" condition than in the "pen in the lips" condition. Moreover, Havas et al. (2010) showed that involuntary movements of facial muscles responsible for frowning are used in simulation of unpleasant events.

To conclude, the aim of the present research was to investigate whether simulation of positive emotions is implicated in "online" and "offline" discourse comprehension. The results demonstrated that emotional bodily states facilitate "online", but not "offline" discourse comprehension. The reported findings contribute to a better understanding of how embodiment and language processing are interconnected and extend the previous literature by focusing on a more global discourse level.

CHAPTER 4

Discourse Comprehension and Simulation of Spatial Dimension

Abstract

Thus far, the previous two experiments provided evidence that emotion simulation is involved in comprehension of discourse that explicitly conveys emotional information. However, a number of studies from the domain of perception suggested that embodied representations get activated even when individuals process sentences that implicitly convey information relevant to comprehension. Therefore, the two major goals of the present study were to demonstrate that people mentally represent the perceptual information implied by a discourse description and that perceptual simulation facilitates both "online" and "offline" discourse processing. In the experiment reported in this chapter the effect of implied left spatial dimension on target text reading time and "offline" comprehension performance was investigated. Participants read a target text on a computer that implicitly suggested a left spatial dimension of an entity or a person in certain events while their body was turned 90 degrees to the right (matching condition) or 90 degrees to the left (mismatching condition). Additionally, a control condition was included in which participants read the text on a computer without a manipulation of body direction. Discourse processing was measured by "online" (self-paced reading times, vividness of mental imagery, and spatial presence) and "offline" (sequence of events) comprehension measures. The major result was that participants in the matching condition reported higher degree of experienced mental imagery for entities or persons located in the left spatial dimension relative to participants in the control and mismatching conditions, but only when those (entities or events) directed the comprehenders' attention to interaction between two people. No effects were found in other measures. This suggests that people simulate, at least partially, the spatial characteristics of different scenes involving objects or persons, but the effect of simulation processes on comprehension of discourse that implicitly conveys perceptual information, such as spatial dimension, is fragile and quite specific.

4.1. Introduction

In the experiments 1 and 2 it was demonstrated that people construct an emotion simulation of the described event during comprehension of discourse that explicitly conveys emotionally positive information. However, according to Perceptual Symbol Systems (PSS) theory of Barsalou (1999a), simulations not only capture explicit information connoted by the language, but as well implicit information that goes beyond words mentioned in the text. More specifically, Barsalou's (1999a) theory rejects an assumption that there is an arbitrary relationship between a symbol and a referent in the physical world, but suggests instead that the relationship between a symbol and its referent is analogous. That is, if an individual reads a sentence "Mike angrily put a laptop in his backpack", then, apart from including explicit properties and affective sensations described by a sentence (e.g., laptop, backpack, angry state), the simulation of this sentence also includes an implicit property such as size (i.e., a laptop in the bag is closed, and thus is different in size from an opened laptop on a table). Thus, understanding this sentence requires from an individual to actually experience closing a laptop and putting it in a backpack. It is worth noting in this context that while embodied theories are capable of explaining how such inferential information as size is understood by the people, amodal theories are insufficient to account for such an implicit meaning (see Stanfield & Zwaan, 2002, for further discussion).

Barsalou's (1999a) theory has found convincing support in the area of sentence processing. For instance, Stanfield and Zwaan (2001) made a hypothesis that if the relationship between a symbol and a referent is analogous and if any changes in the physical referent cause identical changes in the perceptual symbols that form a simulation, then changing the details of a simulation should affect a subsequent interpretation of the referent. Remarkably, this is just what the researchers found. More precisely, response times for a sentence such as "John put the pencil in the cup" were faster when the implied orientation (vertical in this case) matched the orientation of a pencil depicted in the picture. The reverse was found when the picture orientation mismatched that implied by the sentence. In recent years, research on how various implied features are employed by the comprehenders during sentence processing has burgeoned. As extensively reviewed in Chapter 2 of this thesis, there is now compelling evidence that people also mentally represent such implied visuospatial properties as shape (Zwaan et al., 2002), motion (Zwaan et al., 2004), visibility (Yaxley & Zwaan, 2007), and perspective (Borghi et al., 2004).

The current study was designed to extend the aforementioned research in two ways. First, it investigated whether language comprehension invokes information about the implied spatial dimension. Second, whereas most previous studies used sentence stimuli to test a hypothesis that implied perceptual features are implicated in language processing, the current study used extended linguistic events (texts).

4.2. Experiment 3

4.2.1. Hypotheses and study overview

The current study tested whether the direction of literal body posture consistent with the position in space of a person or an entity implied by a discourse description facilitates "online" (hypothesis one) and "offline" (hypothesis two) language processing. Consider, for instance, a sentence "John stops the car and goes out to buy a sandwich". According to PSS theory (Barsalou, 1999a), comprehension of a sentence like this involves the simulation that includes a left spatial dimension for the character, just as if one were to actually apply the brakes on a driver's seat, open the door adjacent to a driver's seat (on the left side) and leave a car through that door. This is so because to simulate applying the brakes and leaving the car, one must simulate a left location of the driver in the car (at least this is the case in countries where you drive on the right). In other words, reading about a driver walking out of a car should yield a mental representation identical to one that is evoked when one actually sees a driver walking out of a car. Thus, if language processing involves the activation of information describing the spatial dimension, then compatibility between a literal direction of a person's body and the spatial dimension in which a person or entity is located implied by a verbal description should lead to facilitation of discourse comprehension. Therefore, with regards to "online" processing, it was expected that participants should be faster to read a text describing persons or entities located in a left spatial dimension when the direction of their body posture is consistent with the location of a person or an entity connoted by a sentence. With regard to "offline" processing, it was expected that the details of spatial dimension simulation will be retained after reading is completed, and thus will influence the recall of information.

To test these hypotheses, participants were first asked to read a neutral text about protagonist's life on a Faial Portuguese Island of the Azores. Reading times were collected and served as a study baseline for the rest of the experiment to control for individual differences in reading speed. Second, participants were timed on how much time they spent reading the target text that described a man driving a car while thinking about a woman he used to love. Importantly, the text included descriptions of implied left locations in each paragraph of the text.

Participants in the matching condition read the text on a computer while their body was turned 90 degrees to the right. Participants in the mismatching condition read the text on a computer while their body was turned 90 degrees to the left. Participants in the neutral (control) condition read the text normally without a manipulation of direction of body posture. Pictorial information on how participants read the text is given in Figure 4.1.

After reading the target text, all participants were asked to fill in a paper-based questionnaire that assessed their general mental imagery, mental imagery regarding specific events from text, spatial presence, and "offline" comprehension of the events described in the target text. In the end of the experiment participants were interviewed what they thought about manipulation with the body posture.

Figure 4.1. Different ways in which the direction of body posture was manipulated in Experiment 3. From left to right, the author demonstrates how participants read the text while their body was turned 90 degrees to the right (matching condition), 90 degrees to the left (mismatching condition), and when participants read the text naturally (neutral control condition)

4.2.2. Method

4.2.2.1. Participants

A total of 63 (60 right-handed and 3 left-handed), native Portuguese-speaking participants (M_{age} = 23.73, SD_{age} = 7.45) from psychology and sociology classes at University of Algarve volunteered to participate in the experiment. 19 participants were male (M_{age} = 25.72; SD_{age} = 9.37), 44 were female (M_{age} = 22.91; SD_{age} = 6.46).

4.2.2.2. Design and materials

The experiment was a single factor between-participants design. Participants were randomly assigned to one of the three aforementioned body direction conditions: body turned 90 degrees to the right (matching condition), body turned 90 degrees to the left (mismatching condition) and body not turned either to the left or right (neutral condition).

Materials consisted of two texts (tutorial and target) and a questionnaire. Tutorial text was emotionally neutral and target text, among other events, included a description of scenes in which entities or persons were located in the left spatial dimension. For example, implied left movements associated with a left spatial dimension included a description about the driver leaving a car, driving a car, etc. Implied left locations associated with a left spatial dimension included a heart, a wedding ring, etc. Thus, the left spatial dimension was only implied by the text and not named directly. Both texts were constructed to have seven paragraphs of exactly the same size. That is, the size of paragraphs in the tutorial text matched the size of paragraphs in the target text (e.g., paragraph one in both texts had 450 characters including spaces). Importantly, each paragraph of the target text described at least one implied left location or movement associated with a target location. Approximate English translation of the complete versions of tutorial and target text is given in Table 4.1 and Table 4.2, respectively. Portuguese original versions of tutorial and target texts are given in Annex H and Annex I, respectively.

Table 4.1

Approximate English Translation of the Tutorial Text Used in Experiment 3

1	It was almost summer. To be more precise, it was the end of May. I didn't even have to go there. I was only supposed to go to Faial to present my book. However, something strange happened at the market in Lisbon. While I was giving autographs to fans, I noticed a girl who was looking at me. Suddenly, she approached me and said, "I'd like to use an opportunity before you begin the presentation. My name is Silvia".
2	We start walking together. We made a deal that we would not go by the end of the road, but stop in the middle of the road and sit on the lava rock nearby, whose shape reminds visitors of human body. Everyone can choose his own lava rock. Here the wind is not very strong as well as the noise of the sea. Sometimes the noise of the wind absorbs the noise of the sea, as a result of which you can see the sea, but cannot hear it. The wind and the sun are similar to flames of fire.
3	At night the weather gets slightly fresher. The earth, however, is still warm and is emitting lots of heat. If you step on it, you can feel how the warmth is reaching your knees making you feel as if you were in the middle of a bonfire. There is more sun on Arcos highway than in any other place, it starts burning your body only after making a few steps. And everything is trembling, including the body. It's a never-ending heat.
4	In the distance one can see the first lights of Madalena. Just a few lights, the first illumination of the principal village. The bar on the square is still opened as well as the restaurant with no one inside. At this season of the year, one can meet a few tourists, fortunately, only a few tourists.
5	I sound as if I have never been a tourist. I am leaving, so why should I bother who comes here? An old habit wanting to know everything, even when far away. Wherever I go I wonder if locals do the same as tourists like to do. I really think that they don't, that there are two different and parallel lives: one of the tourist and the other of the local.
6	The day is starting to get heavy and I start getting tired. I have no idea what made me come here. Memories…There is nothing better than a memory of failed love, one can think of many different scenarios, creating an impression that everything is only ahead. Who knows what would have come out of failed love of it suddenly became a true love.
7	Features of present life. You add them when you cannot remember the memory. They change it to the extent that you end up remembering something different, something shaped by your life. Memories, memories, memories…

Table 4.2

Approximate English Translation of the Target Text Used in Experiment 3

1	He looks at his wristwatch, it is 21.00. He leaves her behind with the pain he was forced to accept. The rush of freedom quickens his heart rate, feeds his wildest dreams of living a normal life. The thirty-four years of his entire existence, the existence that led up to this moment, will never be remembered again. He cannot rewind time back on his wristwatch to bring his wife back.
2	The heart, already torn into pieces, makes the blood flow with an incredible speed all over his body as he watches other cars passing by his car window. His deep blue eyes in the darkness of the moment are full of sorrow and tears. His whole body seems to be numb as if the discharged battery. But he knows he has to forget. If running long and hard erases the past, then he will succeed.
3	While driving his car, he is dreaming her. He is dreaming of the time they got married and exchanged wedding rings; he is dreaming of the time he was teaching her how to mount a horse; he is dreaming of the time he was unlocking the door of the house after a hard day and she was there, waiting for her man. Finally, he is dreaming of the smell of her skin, of the smell of her perfume, of the smell of her presence… Now it is all gone. The world seems to be grey, cold, and meaningless.
4	The horrible roar of the motor of the car makes it fly with an incredible speed, outrunning car after car. But soon he understands that in his desire to escape from the world he fails. He stops the car and turns back in his seat to see if he escaped from her, from the past, from himself…
5	He stares out of the window, shuddered at the night that obstructed his view. “Where am I?” he asks. But there is no one to answer; there is no one who can help him overcome the pain that is coming deep from the bottom of his broken heart. Pulling up all the strength, he takes the deep breath and goes out of the car. Already the air feels icy, and he can sense the chill of night approach. The sky grows with clouds; the wind is blowing into his face.
6	He takes out a cigarette from the pocket of his shirt and smokes. After the fatigue of hunger, the violent shaking, the overflowing humidity, the smell of the cigarette is the only consolation for him out there in the middle of nowhere. Suddenly, the rain comes down in hard sheets of water, and he understands he is absolutely miserable in this big world.
7	He wished he was dreaming. But it is not a dream. Despite the adrenalin pulsing through his heart, the fatigue, the bitter cold and lack of food, he still feels her presence. She is still there with him on the wedding ring of his hand, symbolically declaring her eternal love for him…

4.2.2.2.1. Measures of "online" discourse comprehension

Collection of reading times. Reading times were collected for whole paragraphs as readers normally read the text.

Completion of questionnaire. Participants were asked to fill in the questionnaire that measured their vividness of mental imagery and feeling of spatial presence. Additionally, three more measures testing for the vividness of imagery were included to build stronger theoretical conclusions. Recall that in the previous two experiments the scale of vividness of mental imagery of Marks (1973) did not reveal any significant differences in responding among the participants of matching, mismatching, and control conditions. However, it was hypothesized (see "General Discussion" section of Chapter 3) that no differences could be detected due to the fact that the scale of mental imagery of Marks (1973) is designed to test imagery effects in comprehension of text in general, thus not allowing to check how mental imagery unfolds as a climatic and spontaneous process in reading (see Long et al., 1989, for discussion). Therefore, to address this ambiguity, participants' mental imagery was assessed with seven additional items that tested their mental imagery with regard to specific events from the target text that contained a description of implied left locations or movements associated with a left spatial dimension.

One issue is important in this context. Many embodied theories (e.g., Barsalou, 1999a, Zwaan, 2004) have argued that simulation consists of many components of different experiences, such as, for instance, possible actions, visuospatial properties, background situations, interactions among people, interoceptive sensations, etc. Thus, these theories predict that a perceptual representation, for instance, for a "heart" would be created from a different series of perceptual symbols for different components of the referent (e.g., shape, size, spatial dimension). Similarly, a perceptual symbol, for instance, for a "driver" would be also created from a different series of perceptual symbols for different components of the referent (e.g., location, size, shape, action, spatial dimension). That is, an implied left spatial dimension for such target variables of this research as "heart" and "wedding ring" is the only perceptual symbol that these variables have in common. This suggests that a reported degree of experienced mental imagery for these variables may vary, considering that they include other perceptual symbols that may significantly alter the construction of an overall simulation for the concept. Clearly, it is theoretically impossible to find concepts that share all perceptual symbols for different components of the referent implying the same spatial dimension. However, it is possible to classify such variables according to certain unified principles. For instance, a concept “heart” in the sentence “I could imagine a sound of a heart beating” is similar to a concept “wedding ring” in the sentence “I could imagine a wedding ring in his hand” in that they both describe a static left location of a concept (i.e., a heart is located near the center of the chest; a wedding ring is on the fourth finger of the left hand). Similarly, a concept “wedding ring” in the sentence “I could imagine how the couple exchanged wedding rings” is similar to a concept “mount a horse” in the sentence “I could imagine how a man taught a woman how to mount a horse” in that they both describe an interaction between two people in space and share a relevant spatial dimension of a person or entity (i.e., location on the left side). Therefore, to at least partially resolve this ambiguity, the items of the questionnaire were classified into three groups: items describing static locations in the left spatial space, items describing movements that involve one person in the left spatial space, and items describing movements that involve two persons in the left spatial space.

- *Vividness of mental imagery*

To test the vividness of mental imagery VVIQ Scale of Marks (1973) was adapted and participants were asked to rate their tendency to mental imagery while reading the target text on a 7-point semantic differential scale: vivid-vague, clear-unclear, indistinct-distinct, sharp-dull, intense-weak, lifelike-lifeless, fuzzy-unambiguous. The scale is presented in Table 3.4 of the previous chapter (p. 111).

- *Spatial presence*

To test the feeling of presence, the subscale of Self Location of the Spatial Presence Scale (Vorderer et al., 2004) was applied. It is a seven-item instrument aimed at assessing participants’ feeling of self-location in a virtual world. Participants had to rate their illusory self-location (e.g., “I felt like I was part of the environment in the presentation”, “I felt like I was actually there in the environment of the presentation”) on a 7-point scale, ranging from (1) *completely disagree* to (7) *completely agree*. The subscale is presented in Table 3.5 of the previous chapter (p. 111).

- *Vividness of mental imagery regarding static locations in the left spatial dimension*

Participants' task was to rate their degree of mental imagery on a 7-point scale, ranging from (1) *completely disagree* to (7) *completely agree*. The items used in the questionnaire are presented in Table 4.3 (see Annex J for a Portuguese version).

Table 4.3

The Items Used to Measure Vividness of Mental Imagery Regarding Static Locations in the Left Spatial Dimension in Experiment 3

	Totally disagree						**Totally agree**
I could imagine the beating of a man's heart	1	2	3	4	5	6	7
I could imagine the wedding ring on a man's hand	1	2	3	4	5	6	7

- *Vividness of mental imagery regarding movements that involve one person in the left spatial dimension*

Participants' task was to rate their degree of mental imagery on a 7-point scale, ranging from (1) *completely disagree* to (7) *completely agree*. The items used in the questionnaire are presented in Table 4.4 (see Annex J for a Portuguese version).

Table 4.4

The Items Used to Measure Vividness of Mental Imagery Regarding Static Locations in the Left Spatial Dimension in Experiment 3

	Totally disagree						**Totally agree**
I could imagine a man driving fast	1	2	3	4	5	6	7
I could imagine a man turning back in his driver's seat	1	2	3	4	5	6	7
I could imagine a man going out of the car	1	2	3	4	5	6	7

- *Vividness of mental imagery regarding movements that involve two persons in the left spatial dimension*

Participants' task was to rate their degree of mental imagery on a 7-point scale, ranging from (1) *completely disagree* to (7) *completely agree*. The items used in the questionnaire are presented in Table 4.5 (see Annex J for a Portuguese version).

Table 4.5

The Items Used to Measure Vividness of Mental Imagery Regarding Movements that Involve Two Persons in the Left Spatial Dimension in Experiment 3

	Totally disagree						**Totally agree**
I could imagine a couple exchanging wedding rings on the ceremony	1	2	3	4	5	6	7
I could imagine a man teaching his wife how to mount the horse	1	2	3	4	5	6	7

4.2.2.2.2. Measures of "offline" discourse comprehension

To measure "offline" comprehension of discourse, participants were asked to sequence statements from the text in proper chronological order. Sequencing refers to the identification of the components of a story, such as the beginning, middle, and end, and the primary goal of this task is to test the ability of the comprehenders to sequence major events from the text within the larger context. Therefore, the main rationale for including this task was to investigate whether perceptual simulations could potentially contribute to the recall of global messages of the text rather than details. Another reason to use this method of reading assessment is that open-ended and inference questions designed to test the effect of emotion simulation on comprehension (described in Chapter 3) were failures. In fact, the means for explicit comprehension were very low (30-40% correct) even in the control condition, suggesting that open and inference questions could be too demanding for participants. In brief, the substitution of previous measures of comprehension by the sequencing comprehension task was done with an idea to try easier comprehension questions in detecting the effect of simulation on "offline" discourse comprehension. It is worth noting in this context that psychology literatures also stress the importance of considering the various response formats by which reading processing is assessed (see Fletcher, 2006, for review). The items used in the questionnaire are presented in Table 4.6 (for a Portuguese version see Annex J).

Table 4.6

The Statements Used in the Sequencing Task in Experiment 3

1. The man is observing through the window of his car how other cars are passing by
2. The man is dreaming of his wife
3. The man walks out of a car
4. The man takes a cigarette from the pocket of his T-shirt and starts smoking

4.2.2.3. Procedure

Participants were contacted directly by the experimenter at university. Everyone was informed about the confidentiality and anonymity of the data, and the possibility to quit the study at any time. Participants were tested individually in a quiet sound insulated room. They sat in a comfortable chair and were told that the experiment would consist of three parts: reading of the tutorial text on a computer, reading of the target text on a computer, and filling in of the paper-based text-related questionnaire.

For the first part of study all participants were instructed to read a neutral text from a laptop computer screen (Model HP G62; screen resolution – 1366×768) under the pretext of having a tutorial session for the computer-based part of experiment. Everyone was informed that each paragraph of the text would be displayed separately on a computer screen and that moving to the next paragraph would require pressing the "Space" key. Participants were also told that their reading performance would be timed, and that they should press the "Space" key as quickly as possible while still maintaining accuracy (Fazio, 1990). Reading times were collected using Stimuli Presentation Software (Version 0.50).

For the second part of study participants were instructed to read the target text that included a description of movements or locations in the left spatial dimension. Participants in the matching condition read the text on a computer while their body was turned 90 degrees to the right. Participants in the mismatching condition read the text on a computer while their body was turned 90 degrees to the left. Participants in the neutral condition read the text normally without a manipulation of body direction.

Reading procedure of the target text was identical to that of tutorial text. When participants finished reading the target text, they were instructed to adopt a normal sitting position and fill in the text-related paper-based questionnaire. Finally, in the post-experimental interview participants were asked what they thought about manipulation with the body posture. This interview was important for the study to check if participants who suspected the purpose of the body direction manipulation tended to regulate their responses more effectively.

4.2.3. Results

4.2.3.1. Preliminary analyses

Preliminary analyses revealed that there was no significant effect of gender on target text reading time after controlling for the effect of tutorial reading time, F (1, 60) = 0.002, $p > .05$. Similarly, by classifying age into the three groups (18-29, 30-49, 50+), it was revealed that there was no significant effect of age on target text reading time after controlling for the effect of tutorial reading time, F (2, 58) = 1.50, $p > .05$. Finally, post-experimental interview confirmed that none of the participants was aware of emotion manipulation.

4.2.3.2. "Online" comprehension measures

Target text reading time. An 8 (Paragraphs 1 to 8) within factor x 3 (condition: matching *vs.* mismatching *vs.* neutral) between factor mixed ANOVA, with tutorial reading time as a covariate, was conducted to analyze the reading times of the target text. Because tutorial and target texts were identical in size, tutorial reading time was chosen as a covariate in order to control for individual differences in reading time. Results showed that tutorial reading time (reported in milliseconds) was significantly related to the participant's target text reading time, F (1, 59) = 75,46, $p < .001$, partial $\eta^2 = .56$. However, there was no significant effect of matching direction on target text reading time after controlling for the effect of the tutorial reading time, F (2, 59) = 1.41, p = .252, partial η^2 = .05. Considering that the one-way analysis of variance (ANOVA) is not significant, and therefore does not protect against inflated Type I error rates in subsequent analyses of data, planned contrasts are not reported (Howell, 2006). Estimated marginal reading time means of participants from all three conditions are provided in Table 4.7.

Table 4.7

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 3

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	21297.25	788.76	19718.96	22875.55
Mismatching	22222.93	792.29	20637.57	23808.29
Matching	23168.31	788.55	21590.42	24746.20

Finally, using Pillai's trace, it was revealed that there was no significant effect of matching direction on the speed with which participants read paragraphs of text, F (14, 108) = 0.74, p > .05. Considering that the multivariate analysis of variance (MANOVA) is not significant, and therefore does not protect against inflated Type I error rates in follow-up a-priori comparisons, planned contrasts are not reported (Bock, 1975). At the same time, a non-significant MANOVA does not allow to fully understand how perceptual simulation unfolds during processing of discourse. To address this ambiguity, MANOVA was followed with separate ANOVAs on each of the dependent variables. To control for the inflation of familywise error rate, a Bonferroni correction was applied to the subsequent ANOVAs (Harris, 1975). The results of univariate test statistics, however, revealed that participants did not significantly differ, nor approached significance in their reading of each of the paragraphs of the target text (see Figure 4.2 and Table 4.8). For the mean differences and exact p-values, see Table 4.9.

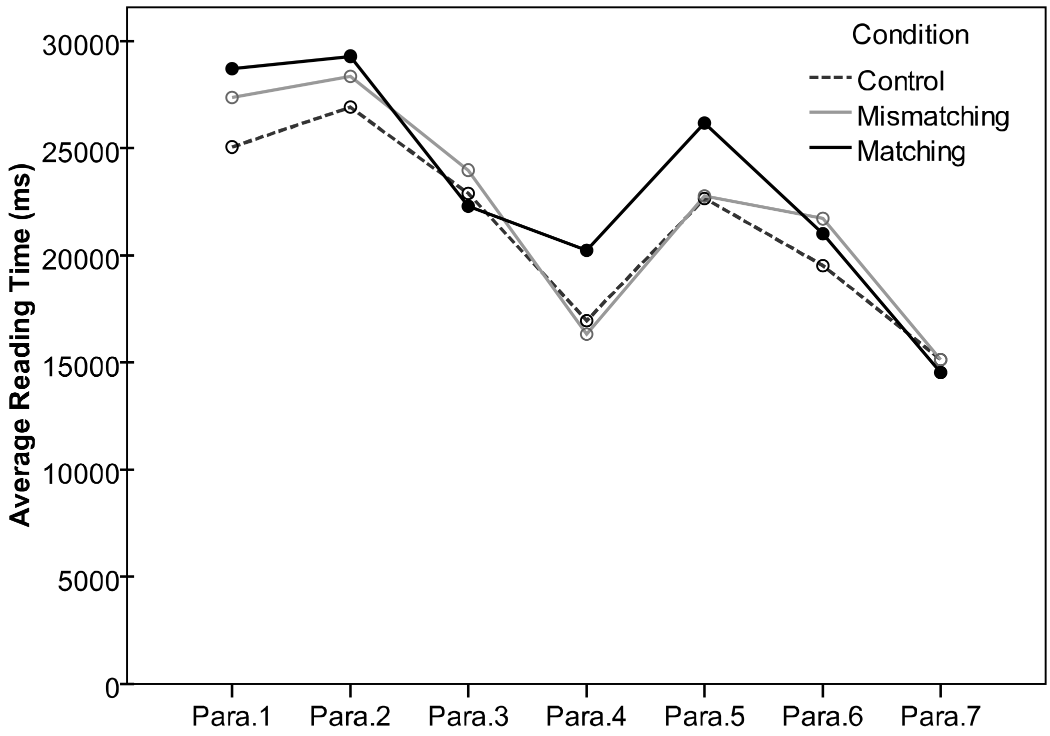

Figure 4.2. Mean reading times in milliseconds (estimated marginal means) for seven paragraphs of the target text according to condition (matching *vs.* control neutral *vs.* mismatching) in Experiment 3

Feeling of presence (Cronbach's alpha = .91). On average, participants felt equally present in the matching condition (*M* = 3.86; *SD* = 1.44), mismatching condition (*M* = 3.22; *SD* = 1.38), and control condition (*M* = 3.31; *SD* = 1.64), *F* (2, 60) = 1.14, *p* > .05.

Vividness of mental imagery (Cronbach's alpha = .76). On average, participants did not significantly differ in their answers in the matching condition (*M* = 4.72; *SD* = 1.26), mismatching condition (*M* = 4.56. *SD* = 0.78), and control condition (*M* = 5.04. *SD* = 0.82), *F* (2, 60) = 1.27, *p* > .05.

Table 4.8

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 3

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Neutral	25049.59	1318.74	22410.80	27688.39
	Mismatching	27351.98	1324.65	24701.38	30002.59
	Matching	28712.71	1318.41	26074.59	31350.83
2	Neutral	26906.79	1035.28	24835.21	28978.37
	Mismatching	28337.11	1039.91	26256.25	30417.96
	Matching	29286.83	1035.01	27215.78	31357.88
3	Neutral	22879.75	844.66	21189.58	24569.91
	Mismatching	23972.52	848.44	22274.80	25670.25
	Matching	22287.62	844.44	20597.89	23977.35
4	Neutral	16944.88	1569.91	13803.50	20086.27
	Mismatching	16306.76	1576.94	13151.32	19462.21
	Matching	20214.43	1569.51	17073.85	23355.02
5	Neutral	22654.25	2142.83	18366.45	26942.05
	Mismatching	22763.63	2152.43	18456.64	27070.62
	Matching	26167.58	2142.29	21880.88	30454.28
6	Neutral	19520.75	1204.93	17109.70	21931.81
	Mismatching	21705.14	1210.32	19283.29	24126.99
	Matching	20993.02	1204.62	18582.58	23403.46
7	Neutral	15124.74	724.21	13675.60	16573.89
	Mismatching	15123.36	727.46	13667.73	16578.10
	Matching	14515.99	724.03	13067.21	15964.76

Vividness of mental imagery regarding static locations in the left spatial dimension. Because this scale had low reliability (Chronbach's alpha < .60), a MANOVA was conducted (Cortina, 1993). Using Pillai's trace, there was no significant effect of the matching condition on the mental imagery regarding static locations in the left spatial dimension, V = 0.10, F (4, 120) = 1.58, p > .05. Due to non-significance of MANOVA, no follow-up analyses were performed.

Table 4.9

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 3

Para.	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Para.1	Neutral	Mismatching	-2302.39	1875.12	.673	-6054.49	1449.71
		Matching	-3663.12	1861.88	.162	-7388.72	62.49
	Mismatching	Neutral	2302.39	1875.12	.673	-1449.71	6054.49
		Matching	-1360.73	1874.41	1.000	-5111.40	2389.95
	Matching	Neutral	3663.12	1861.88	.162	-62.49	7388.72
		Mismatching	1360.73	1874.41	1.000	-2389.95	5111.40
Para.2	Neutral	Mismatching	-1430.32	1472.06	1.000	-4375.90	1515.26
		Matching	-2380.04	1461.66	.326	-5304.82	544.734
	Mismatching	Neutral	1430.32	1472.06	1.000	-1515.26	4375.90
		Matching	-949.73	1471.50	1.000	-3894.19	1994.73
	Matching	Neutral	2380.04	1461.66	.326	-544.74	5304.82
		Mismatching	949.73	1471.50	1.000	-1994.73	3894.19
Para.3	Neutral	Mismatching	-1092.78	1201.02	1.000	-3496.01	1310.46
		Matching	592.13	1192.54	1.000	-1794.14	2978.39
	Mismatching	Neutral	1092.78	1201.02	1.000	-1310.46	3496.01
		Matching	1684.90	1200.57	.497	-717.42	4087.23
	Matching	Neutral	-592.13	1192.54	1.000	-2978.39	1794.14
		Mismatching	-1684.90	1200.57	.497	-4087.23	717.42

(continued)

Table 5.2 (continued)

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 3

Para.4	Neutral	Mismatching	638.12	2232.25	1.000	-3828.61	5104.85
		Matching	-3269.55	2216.49	.437	-7704.74	1165.64
	Mismatching	Neutral	-638.12	2232.25	1.000	-5104.85	3828.61
		Matching	-3907.67	2231.41	.255	-8372.70	557.37
	Matching	Neutral	3269.55	2216.49	.437	-1165.64	7704.74
		Mismatching	3907.67	2231.41	.255	-557.37	8372.71
Para.5	Neutral	Mismatching	-109.38	3046.89	1.000	-6206.12	5987.44
		Matching	-3513.33	3025.377	.751	-9567.09	2540.44
	Mismatching	Neutral	109.38	3046.89	1.000	-5987.44	6206.20
		Matching	-3403.95	3045.74	.805	-9498.45	2690.55
	Matching	Neutral	3513.33	3025.37	.751	-2540.44	9567.09
		Mismatching	3403.95	3045.74	.805	-2690.55	9498.45
Para.6	Neutral	Mismatching	-2184.39	1713.29	.622	-5612.67	1243.89
		Matching	-1472.27	1701.19	1.000	-4876.34	1931.81
	Mismatching	Neutral	2184.39	1713.29	.622	-1243.89	5612.67
		Matching	712.12	1712.64	1.000	-2714.85	4139.10
	Matching	Neutral	1472.27	1701.19	1.000	-1931.81	4876.34
		Mismatching	-712.12	1712.64	1.000	-4139.10	2714.85
Para.7	Neutral	Mismatching	1.38	1029.76	1.000	-2059.16	2061.92
		Matching	608.76	1022.49	1.000	-1437.24	2654.75
	Mismatching	Neutral	-1.38	1029.76	1.000	-2061.92	2059.16
		Matching	607.38	1029.37	1.000	-1452.38	2667.14
	Matching	Neutral	-608.76	1022.49	1.000	-2654.75	1437.24
		Mismatching	-607.38	1029.37	1.000	-2667.14	1452.38

Vividness of mental imagery regarding movements that involve one person in the left spatial dimension. Because this scale had low reliability (Chronbach's alpha <.60), a MANOVA was conducted (Cortina, 1993). Using Pillai's trace, there was no significant effect of the matching condition on the mental imagery regarding movements that involve one person in the left spatial dimension, $V = 0.15$, $F\ (8,\ 116) = 1.14$, $p > .05$. Due to non-significance of MANOVA, no follow-up analyses were performed.

Vividness of mental imagery regarding movements that involve two persons in the left spatial dimension. Because this scale had low reliability (Chronbach's alpha <.60), a MANOVA was conducted (Cortina, 1993). Using Pillai's trace, there was a significant effect of the experimental condition on the mental imagery regarding movements that involve two persons in the left spatial dimension, V = 0.17, $F\ (4,\ 118) = 2.70$, $p = .034$. Due to significance of MANOVA, some follow-up analyses were performed. More precisely, following the recommendation of Field (2009), the MANOVA was followed up with discriminant analysis to discover the relationships that exist between dependent variables as well as the relationship between the dependent variables and group membership. Discriminant analysis revealed two discriminant functions. The first explained 91,5 % of the variance, canonical $R^2 = .15$, whereas the second explained only 8,5 %, canonical $R^2 = .02$. In combination these discriminant functions significantly differentiated the experimental conditions, $\Lambda = 0.84$, $\chi^2\ (1) = 10.56$, $p = .032$, but removing the first function indicated that the second function did not significantly differentiate the experimental conditions, $\Lambda = 0.98$, $\chi^2\ (1) = 0.96$, $p = > .05$. The correlations between outcomes and the discriminant functions revealed that the variable "mount a horse" loaded more highly on the first function ($r = .82$) than the second function ($r = -.58$); the variable "exchange wedding rings" loaded fairly evenly highly onto both functions ($r = .69$ for the first function and $r = .73$ for the second). The discriminant function plot (see Figure 4.3) showed that the first function discriminated the mismatching condition from the matching condition, and the second function differentiated the control condition from two experimental conditions in which the direction of the body posture was manipulated. It is interesting to note that the difference for the second variate (control *vs.* matching and mismatching) is not as dramatic as for the first variate (mismatching *vs.* matching), suggesting that major differences in responding are to be found between participants of matching and mismatching conditions. Finally, graphical representation of the data for the two target variables of the scale (see Figures 4.4 and 4.5.) also shows a trend indicating that the vividness of mental imagery increases when participants process the text in the direction of body posture consistent with the position in space of a person or an entity implied by a text description.

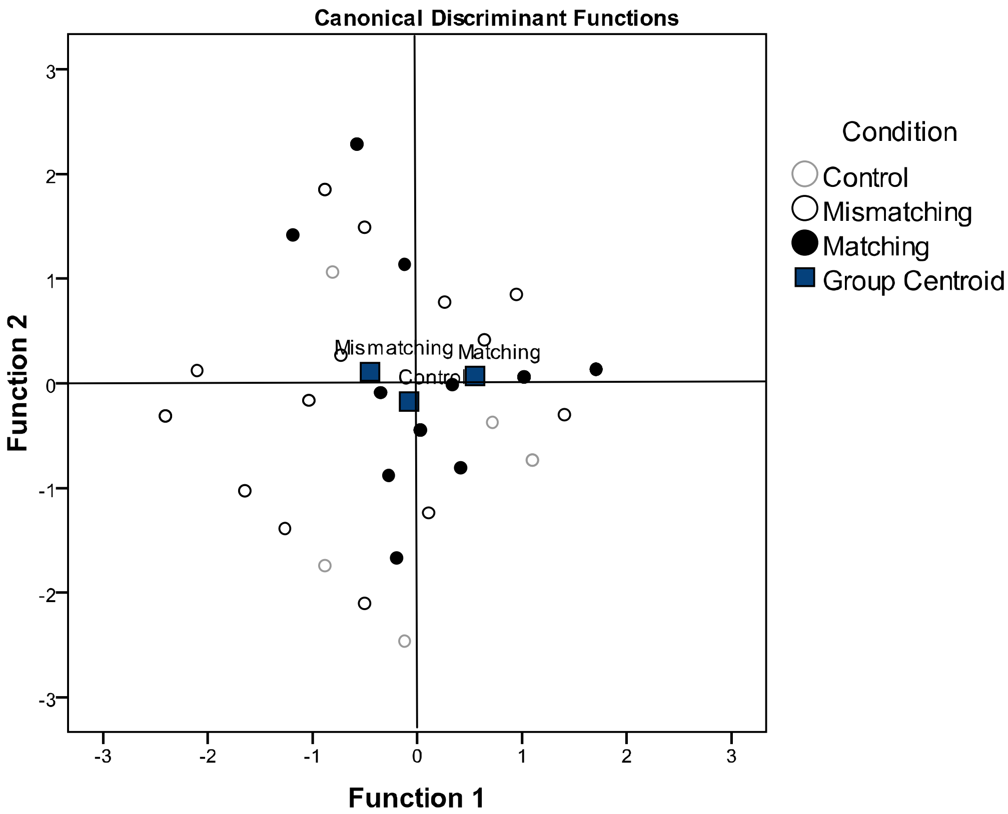

Figure 4.3. Discriminant analysis on mental imagery regarding left movements that involve two persons in the left spatial dimension (conditions: neutral control *vs.* mismatching *vs.* matching)

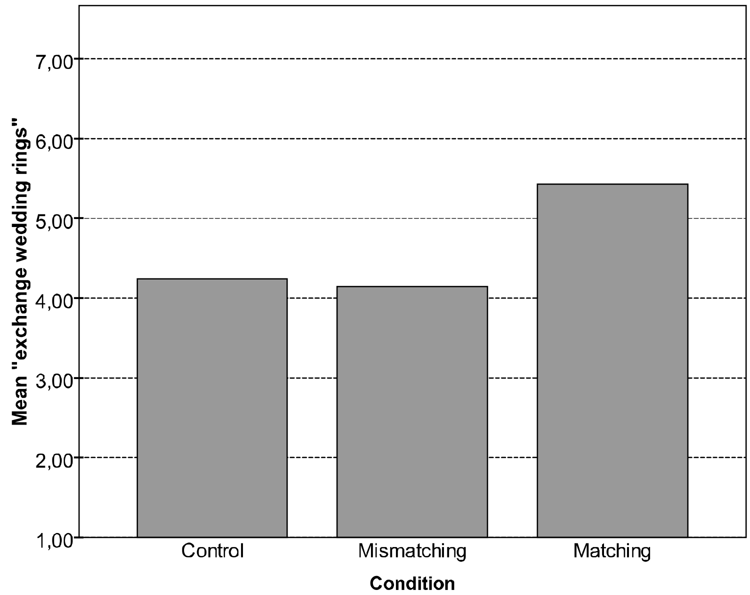

Figure 4.4. Mean responses for the variable "exchange wedding rings" (control neutral *vs.* mismatching *vs.* matching).

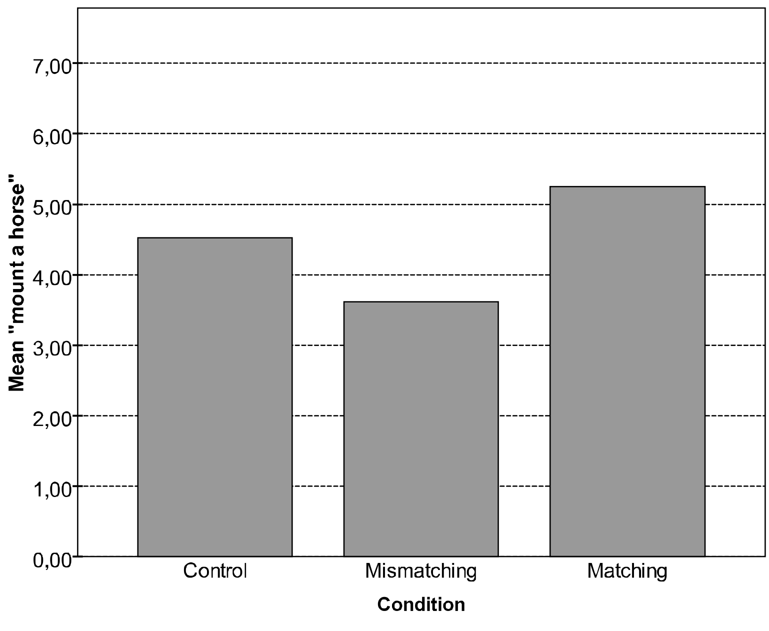

Figure 4.5. Mean responses for the variable "mount a horse" (control neutral *vs.* mismatching *vs.* matching).

4.2.3.3. Measures of "offline" comprehension

Arranging events from the text in the proper chronological order. A one-way ANOVA was conducted on the number of statements listed in the proper chronological order. It was revealed that participants did not significantly differ in their answers in the matching condition (M = 2.00; SD = 1.15), mismatching condition (M = 1.76. SD = 1.04), and neutral condition (M = 1.62. SD = 1.20), F (2, 58) = 0.57, p > .05.

4.3. General discussion

The experiment reported in this chapter of the thesis was designed to investigate whether the direction of literal body posture consistent with the position in space of a person or an entity implied by a discourse description facilitates "online" (hypothesis 1) and "offline" (hypothesis 2) language processing. The results of the experiment provided partial support for hypothesis 1 and no support for hypothesis 2. Specifically, those who read the text while their body was turned 90 degrees to the right (matching condition) reported higher degree of vividness of mental imagery, but only with regard to scenes that described movements involving two persons in the left spatial dimension. The most important factor that presumably contributed to the discrepancy among various measures of mental imagery is the degree of integratability of the body direction into the simulation constructed of the content of discourse. Recall that PSS theory (Barsalou, 1999a) suggests that a relationship between a symbol and its referent is analogous, and thus to simulate the situation one has to actually imagine being a part of the environment of the presentation. For example, a comprehension of the part of discourse describing how the couple exchanged wedding rings in the church would lead to a construction of simulation that includes such perceptual symbols associated with a left spatial dimension as static location (i.e., wedding ring on the fourth finger of the left hand) and perspective (i.e., a bride in the church, according to a Catholic tradition, stays in front of the groom with her left shoulder facing a priest). Point is: a matching direction of body posture might have facilitated the construction of simulation with regards to perspective in the left spatial dimension, but not (or to a lesser extent) left static location, given that perspective seemed to demonstrate higher integratability with the manipulation of body direction than static location (see Figure 4.5). Whereas it may be intuitive that such an explanation is correct, further exploration of this hypothesis is needed.

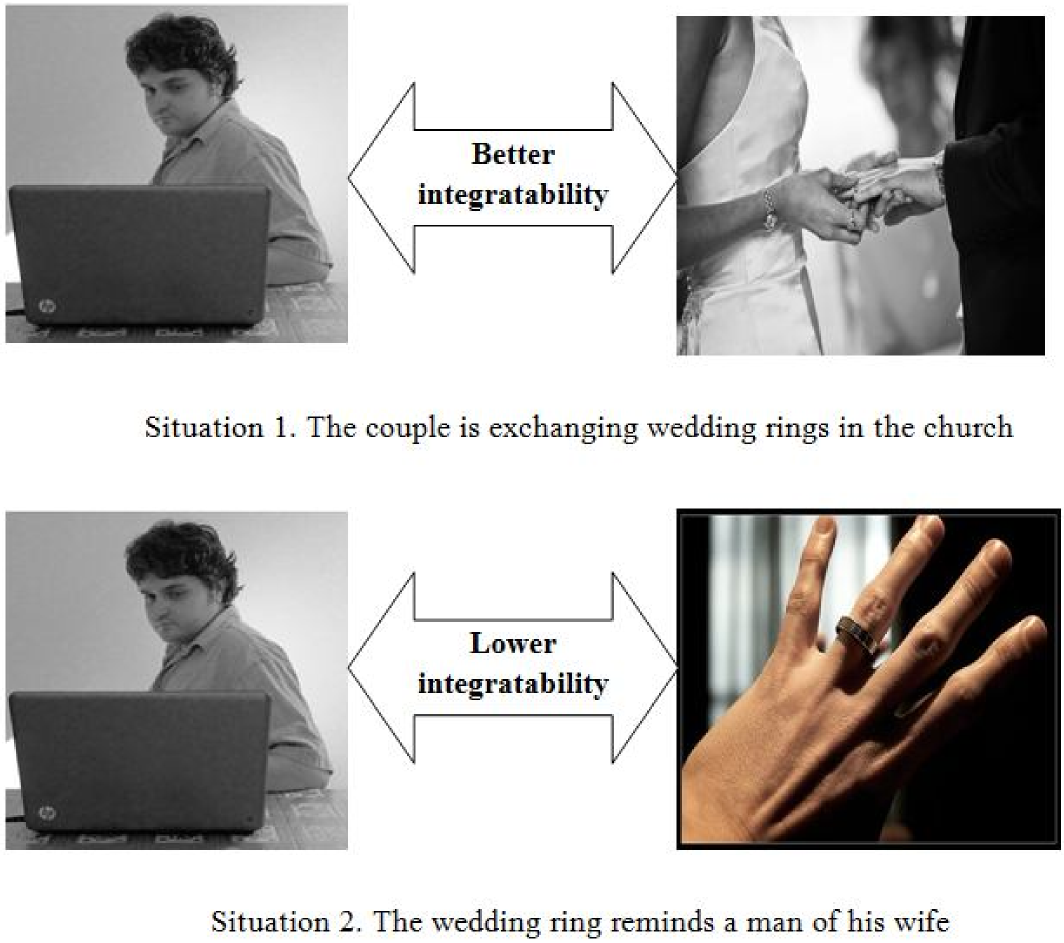

Figure 4.6. From top to bottom, the author demonstrates the possible degree of integratability between the matching direction of body posture and comprehension of the two different (yet somehow similar) situations connoted by discourse.

Nonetheless, the presence of effects in the above-mentioned measures of vividness of mental imagery should be regarded with caution. On the one hand, it is interesting to note that better performance of participants on measures of mental imagery in the congruent condition was not accompanied by poorer comprehension in other "online" and "offline" measures. On the other hand, the presence of null effects for other measures of "online" processing (reading times) and "offline" processing (sequencing task) raises serious concerns that need to be addressed. In the remainder of the discussion the putative explanations of null effects for other comprehension measures are addressed.

The null effects for reading times presumably reflect the high demands of processing the text in the untypical direction of body posture. That is, participants' speed of reading could be affected by the difficulty they faced in adjusting the body to process the text while being turned 90 degrees to the left or right. At the same time, it is worth pointing out that the differences in reading times across conditions are not significant. In fact, the maximum difference that is observed between the mean reading times for neutral and matching conditions is less than two seconds. Of course, a skeptic might argue that the null effects for reading times in this study suggest that bodily states did not play any role in "online" discourse processing. However, if the body did not play any role in the processing of text, then manipulating the body should have no effect on the experienced degree of mental imagery, but it does.

It is worth noting again why obtained effects on questionnaire of mental imagery, which is not a standardized language comprehension measure, are regarded as a support for the hypothesis that perceptual simulation was at least somewhat involved in discourse processing. First, research suggests that object words such as those used in present research (e.g., wedding ring) evoke a perceptual simulation of the denoted objects, and that the simulation gets activated automatically during comprehension and can be consciously inspected by mental imagery measures (Estes, Verges, & Barsalou, 2008). Second, simulation affects both perception and imagery in conceptual processing, and thus measures of vividness of mental imagery manage to at least partially explain whether simulation took place in understanding of information (Wu & Barsalou, 2009). Concluding with a broader point, there is now evidence from eye-tracking studies that the same sensorimotor mechanisms are utilized for viewing, imagining, and remembering elements of the scene. This suggests that higher-level cognition is not separate from lower-level processing (Spivey & Geng, 2001).

With regard to "offline" discourse comprehension measures, there are two alternative explanations of observed null effects. First straightforward explanation is that the direction of body posture had no effect on "offline" processing of text. Note that two previous experiments in the domain of emotional language processing

(Chapter 3) also did not show any effect of simulation on “offline” discourse comprehension. An alternative explanation might be that the effect of simulation on “offline” discourse comprehension can only be captured by more sensitive measures, such as reaction times, that proved to be useful in situations when less sensitive measures (e.g., questionnaire) did not demonstrate any effect of experimental manipulation on performance (Pachella, 1974).

To sum up, this experiment was designed to investigate whether the direction of literal body posture consistent with the position in space of a person or an entity implied by a discourse description facilitates “online” and “offline” language processing. It was found that congruent direction of body posture benefited some measures of “online” comprehension, such as mental imagery regarding interaction between two people, but there was no effect of congruent body direction on “offline” language comprehension. This pattern of results suggests that there is considerable specificity in the simulations constructed during processing of discourse describing events that implicitly suggest a particular spatial dimension for an object or person. The primary contribution of this article is confirmation of a prediction made by a PSS theory (Barsalou, 1999a) on the analogous relationship between a symbol and its referent. More specifically, the obtained results showed that even implicit properties of simulations, such as spatial dimension, are at least partially involved in comprehension of large language segments such as discourse. Whereas there are clearly many questions in this experiment that must await further empirical investigation, the exploration of questions like these is useful as it provides a useful starting point to decide on appropriate experimental strategies in the future.

CHAPTER 5

Discourse Comprehension and Simulation of Metaphorical Actions

Abstract

The previous three experiments revealed that simulations may not only capture explicit information connoted by the language (Chapter 3), but as well implicit information (Chapter 4) that goes beyond words mentioned in the text. The two experiments reported in this chapter extend these findings by investigating whether comprehension of discourse describing metaphorical actions that are physically impossible to perform also requires the construction of a simulation. Two experiments were conducted to investigate whether action simulation influences "online" and "offline" comprehension at a more global discourse level. Participants read a text describing a protagonist making metaphorical forward movements while their body movement (Experiment 4) and body posture (Experiment 5) were manipulated to be either prepared or not prepared for processing of action-congruent information. "Online" comprehension was measured by collecting reading times. "Offline" explicit and implicit processing of discourse were measured on accuracy to comprehension questions and the amount of time it took participants to recognize words from discourse as well as judge sentences as correct or incorrect with respect to the content of text. The results revealed that action simulation affected recognition (Experiments 4 and 5) and judgment times (Experiment 4) regarding "offline" explicit comprehension measures, and accuracy and judgment times regarding "offline" implicit comprehension measures (Experiments 4 and 5). The effect of matching action on "online" processing was fragile. These findings support the language and situated simulation theory, suggesting that simulation system affects to a greater extent comprehensive processing of information based on deduction and interpretation and to a lesser extent shallow processing based on information explicitly provided in the text.

5.1. Introduction

Previous research in the domain of language processing demonstrated that comprehension of sentences describing concrete situations requires the construction of action simulation of the described event (e.g., de Vega, et al., 2004; Glenberg & Kaschak, 2002; Zwaan & Taylor, 2006). This evidence is supported by several recent findings from neuroscience which showed that processing of words describing certain objects or actions requires the activation of the same neural regions that are routinely activated when one actually perceives or performs actions with regard to the referent of the words (e.g., Boulenger, et al., 2006; Martin & Chao, 2001; Gernsbacher & Kaschak, 2003; Hauk, et al, 2004; Isenberg et al., 1999; Kan et al., 2003; Pulvermüller, 1999, 2002; Tettamanti et al., 2005).

More recent work in cognitive science suggested that comprehension of sentences describing abstract situations requires the involvement of action simulation to the same extent as comprehension of concrete sentences. For example, in one line of research Glenberg et al. (2008) demonstrated that comprehension of abstract sentences modulates action systems. Participants were asked to read sentences describing transfer and judge if a sentence was sensible by responding in the direction that either matched or mismatched the direction connoted by the sentence. The major result was that participants were faster to decide whether abstract sentences describing toward transfer (e.g., "Anna delegates the responsibilities to you") and away transfer (e.g., "You delegate the responsibilities to Anna") were sensible when they made a response in the direction (toward vs. away) that was consistent with the direction of movement implied by the sentence. As another example how comprehension of abstract concepts modulates action systems, Santana and de Vega (2011) asked participants to read metaphors (e.g., "His talent for politics made him rise to victory") and abstract sentences similar in meaning to the metaphors (e.g., "His working capability made him succeed as a professional"), and then perform a hand motion (while reading the sentence verb) that either matched or mismatched the direction implied by the sentence. The results showed that responding was faster when there was a match between the direction of literal movement and that implied by the sentence.

Another line of research addresses how literal movement appropriate for the metaphorical phrases facilitates language comprehension. For instance, Wilson and Gibbs (2007) produced evidence on how engaging in real body action or merely imagining making a specific body movement improves comprehension of metaphorical phrases. More precisely, in this research participants learned to make various body movements or imagined making a particular body movement and then were presented with metaphorical phrases (e.g., grasp a concept) that either matched or mismatched a previous body action (e.g., grasping movement). The results revealed that phrase reading times were faster when the previous literal or imagined body movement was consistent with the action implied by the sentence. In a similar experiment, Gibbs et al. (2006) demonstrated that even watching someone make a congruent body movement induced comprehension of metaphorical phrases describing actions physically impossible to perform (e.g., watching someone make a stretching motion while processing the phrase "stretch for understanding"). For a more complete reviews and discussion of these and similar findings see Gibbs (2006), Gibbs and Perlman (2010), Ritchie (2008, 2009), and Semino (2010).

The findings from the above-mentioned studies converge on the conclusion that understanding of phrases or sentences describing abstract movement calls on the same bodily and neural states that are used in control of literal action. The present research was designed to explore further the importance of action simulation in processing of language describing abstract metaphorical concepts. It extends Wilson and Gibbs' (2007) work that has examined how body action influences metaphor comprehension and shares the view that simulation is necessary for comprehension. At the same time, the present research differs from Wilson and Gibbs' (2007) research in several aspects. First, it was tested how action simulation affects comprehension of extended linguistic events such as discourse. Interest for this question is inspired by previous discussions on the paucity of research regarding the role of simulation during discourse comprehension (Fischer & Zwaan, 2008) as well as the importance of testing language comprehension at a more global discourse level (Graesser, et al., 1997; Sparks & Rapp, 2010). Second, whereas Wilson and Gibbs (2007) examined the influence of body action on "online" measures of comprehension (reading times), this research investigated how body action affects both "online" discourse processing and "offline" explicit and implicit discourse processing. The study of this question is motivated by previous research that stressed the importance of testing overall process of comprehension that includes both "online" reading (e.g., word decoding, syntactic processing) and "offline" postreading (e.g., drawing conclusions, making inferences, etc.) processes (Goldman & Varma, 1995; Graesser, et al., 1994; Kintsch, 1988; Trabasso & Suh, 1993; van der Broek et al., 1999; Zwaan & Radvansky, 1998; Zwaan & Singer, 2003).

As discussed in previous chapter of this thesis, earlier findings support the prediction that simulation may affect "offline" discourse processing. For example, Pecher et al. (2009) instructed participants to read a list of sentences describing objects and then to perform recognition memory task on the pictures. It was found that recognition performance was better if the picture matched the implied shape or orientation of the object in an earlier sentence. Importantly, recognition task was better even when sentence reading and picture recognition were separated in time (45-min delay). As another evidence for this prediction, Glenberg et al. (2004) demonstrated that embodied interventions help children better remember parts of texts and answer inference questions. Finally, language and situated simulation theory (Barsalou et al., 2008) proposes that when simulation system dominates in a reading comprehension task, people tend to build comprehensive mental representations from inferences (information that goes beyond information mentioned explicitly) computed during processing of discourse. This in turn allows to predict that inferences generated "online" might potentially affect "offline" implicit comprehension of text.

5.2. Hypotheses and study overview

The embodied simulation account of cognition suggests that understanding of language describing metaphorical actions involves constructing a sensorimotor simulation of the described event. If such an account is correct, then shifting the body into an appropriate action state congruent with the discourse meaning should facilitate discourse processing. That is, participants whose bodily systems are prepared for processing of language implying congruent body movements (facilitation condition) should demonstrate better performance on measures of "online" processing and "offline" explicit and implicit processing relative to participants whose bodily systems are not prepared for such processing (control condition).

To test this prediction, in experiments 4 and 5 participants were asked to read a neutral tutorial text about a boy telling a story about his school life. Reading times were collected and served as a study baseline for the rest of the experiment to control for individual differences in reading speed. Second, participants were timed on how much time they spent reading the target text, an adapted speech of President Lyndon Johnson on envisions of transforming America into a “Great Society” free of poverty, crime, and racism (Torricelli & Carrol, 1999). The text contained metaphors and metaphorical phrases implying forward movements. More concretely, in Experiment 1 participants in the advanced facilitation condition first exercised on a stationary bike and then read the text standing in front of the monitor while their lead leg was advanced for 40 centimeters from their follow leg. In Experiment 2 participants in the basic facilitation condition read the text in the same way as participants from the advanced facilitation condition, with the exception that they did not exercise on a stationary bike prior to reading the text. Participants in the control condition both in Experiment 1 and Experiment 2 read the text standing in front of the monitor with their feet together. After reading the text, participants in all conditions answered a set of filler questions and completed a comprehension test that included judgment and recognition tasks. Discourse comprehension in a judgment task was assessed by textually explicit and textually implicit sentences (see Pearson & Johnson, 1980, for a discussion). Participants’ task consisted in judging if a sentence is correct with regard to text’s content. In a recognition task participants were presented with words and had to decide if they belonged to a text. Performance indicators were text’s reading times, accuracy in recognition task, accuracy in judgment task, and response times. Pictorial information on how the motor system was manipulated is given in Figure 5.1.

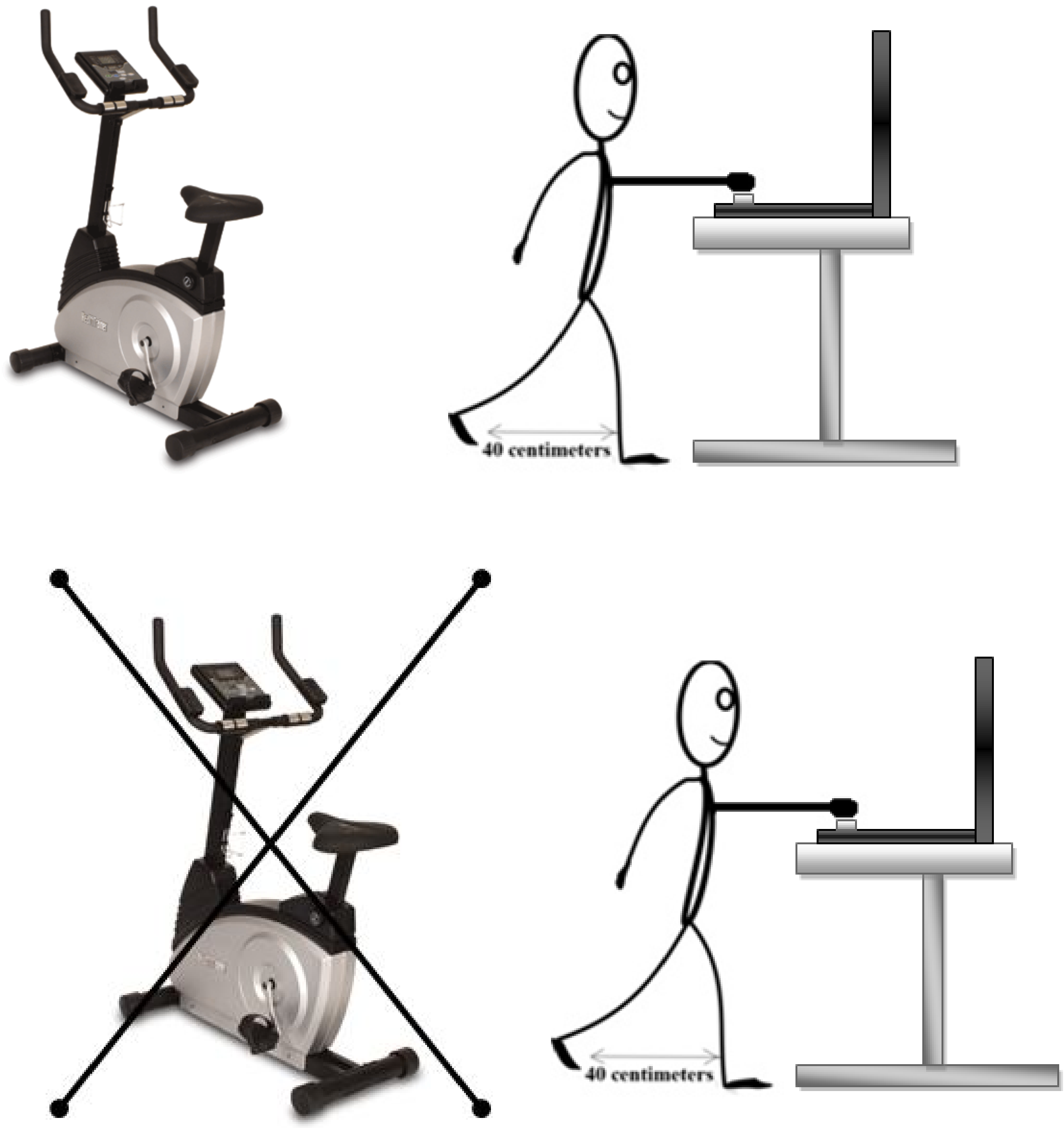

Figure 5.1. Pictorial information on how motor system was manipulated in Experiments 4 and 5. From top to bottom, it is demonstrated that participants in the advanced facilitation condition from Experiment 4 first exercised on a stationary bike for a minute and then were requested to approach a computer placed on a rostrum, advance their lead leg for 40 centimeters from their follow leg and read paragraphs of the target text by pressing the “Space” key; participants in the basic facilitation condition from Experiment 5 read the text in the same way, with the exception that they did not exercise on the bike prior to text reading.

5.3. Experiment 4

If understanding of discourse describing metaphorical forward movements requires the re-activation of modality-specific states that are involved in real action, then engaging in body movement and adopting a body posture appropriate to the metaphorical phrases should facilitate discourse processing. More broadly, it was expected that matching body movement and matching body posture would facilitate "online" processing and "offline" explicit and implicit discourse comprehension, compared to no action (control) condition.

5.3.1. Method

5.3.1.1. Participants and design

The sample consisted of 38 right-handed, native Portuguese-speaking university students (M_{age} = 23.03, SD_{age} = 5.53). Nine participants were male (M_{age} = 26.33; SD_{age} = 7.37), 27 were female (M_{age} = 22.07; SD_{age} = 4.67), and two participants did not indicate gender. The experiment was a single factor between-participants design. Participants were randomly assigned to one of the conditions: advanced facilitation or control condition.

5.3.1.2. Materials

Materials consisted of two texts (tutorial and target) and a comprehension task assessing response times at test. Both texts were constructed to have seven paragraphs of exactly the same size. A target text, a speech of President Lyndon Johnson on envisions of transforming America into a "Great Society" free of poverty, crime, and racism was adjusted to meet research requirements. More precisely, adjustments to the original text were as follows: the size of the text was reduced to seven paragraphs and twelve metaphors and metaphorical phrases implying forward movements were embedded into it. Metaphorical phrases representing forward movements were mentioned in each paragraph of the target text. See Table 5.1 and Table 5.2 for an approximate English translation of the tutorial and target texts used in these experiments. Original Portuguese version of tutorial and target texts is given in Annex K and Annex L, respectively. Importantly, the previous measures of "online" and "offline" discourse comprehension administered through questionnaire (e.g., vividness of mental imagery, spatial presence, open questions, etc.) were not used as they proved ineffective to detect the effect of simulation on discourse comprehension in the previous three experiments.

Table 5.1

Approximate English Translation of the Tutorial Text Used In Experiment 4

1	Everyone calls me Skin and Bones since the first year of school. I am skinny and my face looks waxy, but I never spent a day without eating. Yes, I look hungry and my bones stick trough the skin; in this regard I took after my uncle Nuno who one day was capable of eating two kilos of cod, four potatoes with two liters of wine, and a kilo of bread. Everyone thought he would burst from eating that much. Well, what I want to explain is that my thinness has nothing to do with hunger.
2	Every day I eat two plates of soup with bread for lunch and supper. Before leaving for school my mom would always give me a sandwich for others not to think that life was bad in our house. At the same time, I still got a nickname Skin and Bones. After this nickname I was given the other ones like Walking Stick and Scare Crow, but none of them resisted the popularity of the first one.
3	I don't remember who gave it to me and now this no longer interests me. I am sure that I became a target of school bullies because of that nickname. A bunch of bullies teased me and invented punishments if I was expressing disagreement. Eventually I got accustomed to those jokes and pretended that I found their teasing funny. But only I know what I felt there inside when they were laughing at me. Today no one bullied me despite the fact that there are ten guys in the corridor of the Secretary. They are nervous, talking with each other in search of pretext to play a joke on someone. But today I am not their target.
4	I am certain that it's my last school day. I pulled all my strength together being sure that a new life is soon to start; the better the grade of the diploma. The easier it will be to reach my dreams. I got the best grades in the class. The books seemed open to me and heard the voices whispering me the material of the disciplines. I took revenge, I am sure that no one will pass by me.

(continued)

Table 5.1 (continued)

Approximate English Translation of the Tutorial Text Used in Experiment 4

5	It is possible that I will meet some of those bullies in my career as a white-collar worker and that they will regret for all those bad things they did to me. I feel that I will win all the challenges of my profession. Things already started changing around me; I no longer have the old red clothing that I felt so ashamed to wear. Today I put on the new suit my father bought in the market.
6	All the nights I lived through will never come back. I recall the last one when I was preparing for the bookkeeping exam: my father was resoling the shoe at the entrance door to prepare for the concert he was about to give the following night. I could not ask him to postpone his work, considering that there was no money in the house and that he was earning money for our lunch. I wide opened the eyes to absorb all the information I still had to study.
7	I hid in the room with a candle with an intention to alienate me from the noise. I focused my eyes on books' pages and covered my ears with hands so that nothing could distract me. But the beating of the hammer was still vibrating through my blood.

Table 5.2

Approximate English Translation of the Target Text Used in Experiment 4

1	By protecting the life of our nation and reserving the liberties of our citizens we pursue our own happiness. Our success in that pursuit is the test of our success as a nation. Your imagination, your initiative, and your creativity will help us build a society where the progress is the servant of our needs. For in your time we have the opportunity to move not only toward the rich society and the powerful society, but upward to the Great Society.
2	If we have a false sense of independence, in the journey to the better tomorrow our ships can collide and crash. But if we find commitment to new priorities, to new strategies, and new ways of thinking that ensure that hope will be kept alive, we will break the wall of hesitation and safely navigate our vessel to the better future.
3	So I want to talk to you today about the places where we begin to build this Great Society: in our cities and in our classrooms. Many of you will live to see the day, perhaps fifty years from now, when our population and city land will double, and when we will altogether make a giant step in the direction of building homes, highways, and facilities equal to all those built since this country was first settled. So in the next 40 years we will be building the bridge to pave the path to this Great Society.

(continued)

Table 5.2 (continued)

Approximate English Translation of the Target Text Used in Experiment 4

4	Our society will never be great until our cities are great. On the wings of time we are quickly approaching an era when imagination and innovation become the biggest priorities. Use your imagination and hope as weapons of our progress to the Great Society. As riders in the race do not stop short as they reach the goal, so do you. Go forward, stretch your arms to grasp any single idea that will lead us to the better tomorrow.
5	Our society will never be great until more than one quarter of our society have not finished high school. Each year more than 10,000 high school graduates with proven ability do not enter college because they cannot afford it. And if we cannot educate today's youth, we cannot follow the future with confidence.
6	I face it, we still have many problems in our schools, but at the same time we moved from the road of discord to the road of agreement. While walking on this road we have to go beyond the curricula which are outdated and move along the stream of future to find new ways to stimulate the love of learning and the capacity for creation.
7	These are the two of the central issues of the Great Society. We need to assemble the best thought and the broadest knowledge from all over the world in order to walk into the better future together and open a new chapter in the history of our great nation.

5.3.1.2.1. Measures of "online" discourse comprehension

Collection of reading times. Reading times were collected for whole paragraphs as readers normally read the text.

5.3.1.2.2. Measures of "offline" discourse comprehension

Judgment task

Regarding explicit comprehension, participants were asked to indicate if a sentence, presented on a computer monitor, was correct on the basis of information that comes directly from the text (see Table 5.3). For instance, a sentence "Many students do not enter university because of financial problems" is correct as there is a mention in the text that many high school graduates do not enter college because they cannot afford it. Importantly, participants were presented with the sentences that paraphrased main ideas from the target text. Paraphrasing was chosen in light of previous research suggesting that people tend to rely on semantic representation of ideas described in the language rather than specific linguistic form (Bransford & Franks, 1971). Regarding implicit comprehension, participants were asked to indicate if a sentence, presented on a computer monitor, was correct on the basis of implicit guessing (see Table 5.3). In other words, a response for such type of assessment is provided in the text, but is not obvious as requires reading beyond the lines to find an answer. For instance, it can be inferred that a sentence “Modernization is an important aspect of Great Society” is correct from the fact that in the speech the speaker stresses the importance of building homes, highways, and facilities as means of future prosperity of the country. Finally, two filler sentences were included (see Table 5.3). These sentences were incorrect with respect to the content of the text. For a Portuguese version of sentences see Annex M.

Table 5.3

List of Sentences Used in a Judgment Task for Experiment 4

Measure	**Sentence**
Explicit comprehension	The places where one should seek to construct Great Society are schools and classrooms Many students do not enter university because of financial problems)
Implicit comprehension	Modernization is an important aspect of Great Society Youth is the hope of the country
Incorrect control sentences	In 50 years the population of the cities will be twice smaller Money is an essential aspect of Great Society

Recognition task

In this task participants had to indicate if a word, presented on a computer monitor, was mentioned in the text. Seventeen stimulus words were used: six represented target words (parts of metaphorical phrases) from the text implying forward body movements, such as *advance*, *follow*, *pursue*, *lead*, *approach*, *move*; and six represented control words from the text that do not imply any movement, such as *help*, *society*, *start*, *great*, *ensure*, *can*. (see Annex M for a list of stimuli in

Portuguese). Because of the worry that previous body action or body posture appropriate for the words denoting forward movements may merely remind participants of the words they are asked to recognize rather than help simulate actions described in the text, it was decided to include five false alarm words that implied forward movements, but were not mentioned in the text, such as *run*, *go*, *march*, *cross*, *move*. If manipulation with the motor system helped simulate actions described in the text, then participants should not significantly differ in their responses for the above-mentioned false-alarm words.

5.3.1.3. Procedure

Experiment 4 took part in a quiet sound insulated room. Participants were tested individually and were informed about the confidentiality and anonymity of the data, and the possibility to quit the study at any time. First, all participants were instructed to read a neutral text from a laptop computer screen (Model HP G62; screen resolution – 1366×768) placed on a height adjustable rostrum under the pretext of having a tutorial session for the computer-based part of experiment. Everyone was informed that each paragraph of the text would be displayed separately on a computer screen and that moving to the next paragraph would require pressing the “Space” key. Participants were also told that their reading performance would be timed, and that they should press the “Space” key as quickly as possible while still maintaining accuracy (Fazio, 1990). Reading times were collected using Stimuli Presentation Software (Version 0.50). Second, participants were randomly assigned to one of the experimental groups and asked to read the target text on the same laptop computer. Reading procedure was identical to that of a tutorial text. Participants in the control condition read the text while standing erect with the two feet together. Participants in the advanced facilitation condition first exercised on a stationary bike for a minute (resistance on pedals was set to a minimum) and then read the text while standing erect with their lead leg advanced forward (40 centimeters from the follow leg). To find out which leg was lead, before the experiment a researcher asked participants what their dominant hand (right- or left-handed) was. Additionally, to ascertain that the dominant hand was consistent with the lead leg, participants were also requested to go over the hurdle to see what leg would go over first. This technique was kindly suggested by an athletics instructor.

Remarkably, for all participants the dominant hand was consistent with the lead leg. Third, participants in all conditions were instructed to start the comprehension test that included a total of 33 trials. Importantly, participants in both conditions (control and advanced facilitation) performed the task while standing with the two feet together. First 10 trials represented filler variables and they were included to allow participants to practice the response format. Next, participants performed a judgment task that included three pairs of sentences: two sentences summarized major events from the text mentioned explicitly; two sentences summarized major ideas implied in the text; and two sentences represented control variables as they were incorrect with respect to the content of the text. Participants had to indicate if a sentence presented on the computer screen was correct with regard to the content of the target text. Participants responded by pressing the a-key with their left index finger if the sentence was incorrect or the l-key with their right index finger if the sentence was correct. Additionally, participants were told that their responses would be timed, and that they should respond as quickly as possible while still maintaining accuracy (Fazio, 1990). Once the decision was made by pressing one of the assigned buttons on the keyboard, the word would disappear and the next trial began after a 3 second delay. Finally, participants performed a recognition task that included a total of 17 variables. Variables were randomized and presented in triads: a variable from the text implying forward movement, a variable from the text that does not imply any movement, and a variable representing forward movement not mentioned in the text. Participants' task was to indicate if a word was mentioned in the text. Participants responded by pressing the a-key with their left index if the word was not mentioned in the text or the l-key if the word was mentioned in the text. In the end, participants were asked whether they suspected that the bike exercise and lead leg manipulation were designed to influence their comprehension of discourse.

5.3.2. Results

5.3.2.1. Coding of Variables and Preliminary analyses

Accuracy rate was calculated on the number of correct answers to target variables by coding incorrect response as "0" and correct response as "1". Preliminary analyses showed that there was no significant effect of gender on target text reading time after controlling for the effect of tutorial reading time, F (1, 30) = 1.16, $p > .05$. Similarly, by classifying age into the three groups (18-29, 30-49, 50+), it was revealed that there was no significant effect of age on target text reading time after controlling for the effect of tutorial reading time, F (1, 35) = 0.06, $p > .05$. Finally, post-experimental interview confirmed that none of the participants suspected the purpose of bike exercise and lead leg manipulation.

5.3.2.2. Measures of "online" discourse comprehension

Target text reading time. An 8 (Paragraphs 1 to 8) within factor x 2 (condition: control *vs.* advanced facilitation) between factor mixed ANOVA, with tutorial reading time as a covariate, was conducted to analyze the reading times of the target text. Because tutorial and target texts were identical in size, tutorial reading time was chosen as a covariate in order to control for individual differences in reading time. Results showed that tutorial reading time (reported in milliseconds) was significantly related to the participant's target text reading time, F (1, 35) = 111.63, $p < .001$, partial $\eta^2 = .76$. However, there was no effect of experimental condition on target text reading time after controlling for the effect of the tutorial reading time, F (1, 35) = 0.26, $p = .872$, partial $\eta^2 = .001$. Considering that the one-way analysis of variance (ANOVA) is not significant, and therefore does not protect against inflated Type I error rates in subsequent analyses of data, planned contrasts are not reported (Howell, 2006). Estimated marginal reading time means of participants from both conditions are provided in Table 5.4.

Table 5.4

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 4

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	21844.10	741.90	20338.86	23351.14
AV	22011.08	703.83	20582.24	23439.92

Note: Abbreviation "AF" refers to "Advanced Facilitation"

Using Pillai's trace, it was found that there was a significant effect of matching action on the speed with which participants read paragraphs of text, F (1, 35) = 111.63, p = .018, partial η^2 = .38. Follow-up analyses comparing pairs of conditions (Figure 5.2 and Table 5.5) revealed that participants in the advanced facilitation condition read the target text significantly faster while reading a paragraph 5 (p = .046) and marginally faster while reading a paragraph 3 (p = .066). No significant differences in reading speeds were found for other paragraphs. For the mean differences and exact p-values, see Table 5.6.

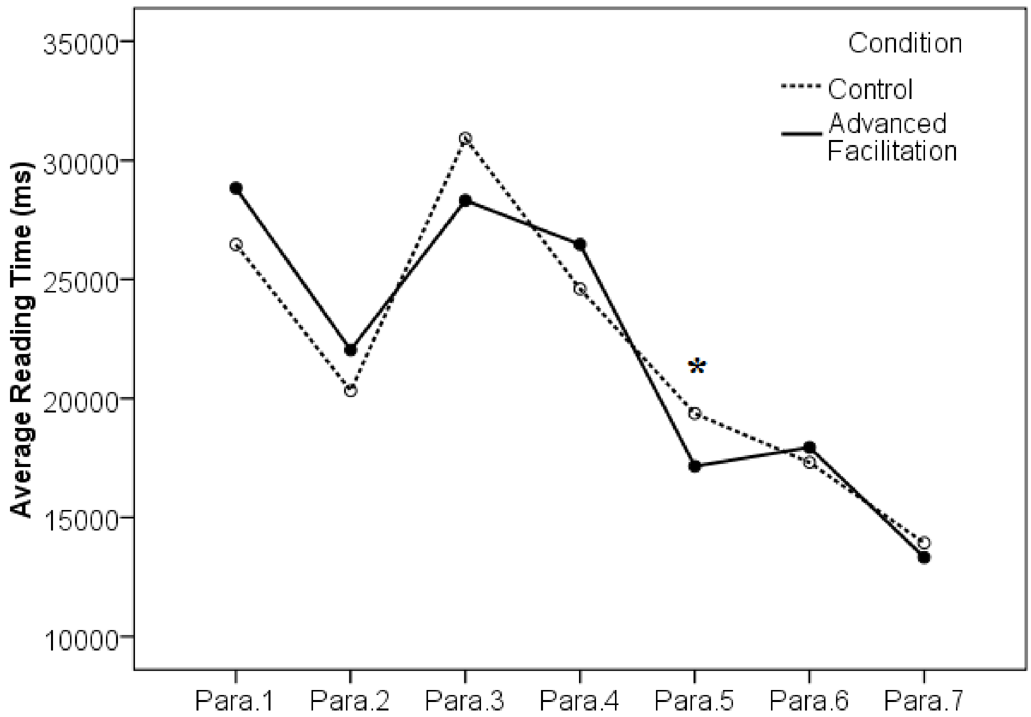

Figure 5.2. Mean reading times in milliseconds (estimated marginal means) for seven paragraphs of the target text according to condition (control *vs.* advanced facilitation) in Experiment 4. *Note*: an asterisk refers to significant pairwise comparisons (p < .05).

Table 5.5

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 4

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Control	26463.49	1211.75	24003.50	28923.48
	AF	28833.15	1149.56	26499.41	31166.88
2	Control	20324.57	901.38	18494.68	22154.46
	AF	22035.43	855.12	20299.45	23771.41
3	Control	30919.02[b]	995.13	28898.81	32939.23
	AF	28314.51[b]	944.05	26397.99	30231.04
4	Control	24598.74	1604.44	21341.55	27855.93
	AF	26470.32	1522.10	23380.30	29560.34
5	Control	19363.93[a]	774.52	17791.56	20936.29
	AF	17154.79[a]	734.77	15663.13	18646.45
6	Control	17313.69	989.42	15305.06	19322.32
	AF	17944.44	938.64	16038.90	19849.98
7	Control	13931.55	689.41	12531.97	15331.12
	AF	13324.91	654.03	11997.16	14652.65

Note: "AF" refers to "Advanced Facilitation". Items marked with ([a]) differ significantly ($p < .05$) and items marked with ([b]) are marginally significant ($p = .066$).

Table 5.6

Pairwise Comparisons Based on Estimated Marginal Means with 95 % Confidence Interval for Difference for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 4

Para.	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	Control	AF	-2369.65	1670.39	.165	-5760.73	1021.42
	AF	Control	2369.65	1670.39	.165	-1021.42	5760.73
2	Control	AF	-1710.86	1242.54	.177	-4233.35	811.63
	AF	Control	1710.86	1242.54	.177	-811.63	4233.35
3	Control	AF	2604.50	1371.77	.066	-180.34	5389.35
	AF	Control	-2604.50	1371.77	.066	-5389.35	180.34
4	Control	AF	-1871.58	2211.71	.403	-6361.59	2618.43
	AF	Control	1871.58	2211.71	.403	-2618.43	6361.59
5	Control	AF	2209.14*	1067.67	.046	41.65	4376.63
	AF	Control	-2209.14*	1067.67	.046	-4376.63	-41.65
6	Control	AF	-630.76	1363.91	.647	-3399.64	2138.12
	AF	Control	630.76	1363.91	.647	-2138.12	3399.64
7	Control	AF	606.64	950.34	.527	-1322.66	2535.94
	AF	Control	-606.64	950.34	.527	-2535.94	1322.66

Note: Abbreviation "AF" refers to "Advanced Facilitation".

5.3.2.3. Measures of "offline" discourse comprehension

Judgment task

Explicit comprehension

An independent-samples t-test on the number of correct responses to sentences checking explicit comprehension of events from text revealed that participants in the control condition (*M* = 0.83; *SD* = 0.38) did not differ significantly in their answers from participants in the advanced facilitation condition (*M* = 0.95; *SD* = 0.22), *t* (26.754) = -1.13, *p* >.05. Similarly, analysis of reaction times revealed that participants in the advanced facilitation condition (*M* = 3786.58; *SD* = 925.81) did not differ significantly in their answers from participants in the control condition (*M* = 4113.49; *SD* = 887.86), *t* (32) = 1.04, *p* >.05 (see Figure 5.3).

Implicit comprehension

An independent-samples t-test on the number of correct responses to sentences checking implicit comprehension of events from text revealed that participants in the advanced facilitation condition (*M* = 0.85; *SD* = 0.29) provided significantly more correct answers than participants in the control condition (*M* = 0.61; *SD* = 0.40), *t* (30.246) = -2.08, *p* = .023 (one-tailed), *r* = .35. Moreover, analysis of reaction times revealed that participants in the advanced facilitation condition (*M* = 2311.44; *SD* = 604.35) were significantly faster to decide whether sentences were correct relative to participants in the control condition (*M* = 2880.28; *SD* = 895.63), *t* (31) = 2.18, *p* = .035 (one-tailed), *r* = .36 (see Figure 5.3).

Control measure

An independent-samples t-test on the number of correct responses to incorrect sentences with regard to the content of the text revealed that participants in the control condition (*M* = 0.58; *SD* = 0.42) did not differ significantly in their answers from participants in the advanced facilitation condition (*M* = 0.58; *SD* = 0.34), *t* (36) = 0.7, *p* >.05. Similarly, analysis of reaction times revealed that participants in the advanced facilitation condition (*M* = 4371.84; *SD* = 1537.49) did not differ significantly in their responses from participants in the control condition (*M* = 5026.03; *SD* = 3325.08), *t* (28) = 0.72, *p* >.05 (see Figure 5.3).

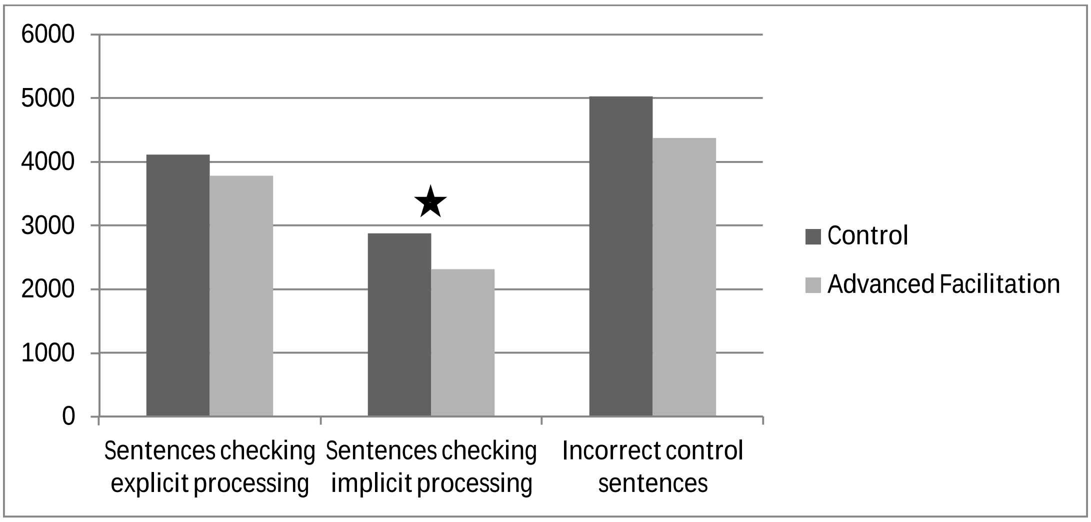

Figure 5.3. Judgment times (reported in milliseconds) of participants in the control and advanced facilitation conditions (Experiment 4). The star corresponds to significant pairwise comparisons (*p* < .05).

Recognition task

Explicit comprehension

*Words from the text implying forward movements (parts of metaphorical phrases).*An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.64; *SD* = 0.22) did not differ significantly in their answers from participants in the advanced facilitation condition (*M* = 0.71; *SD* = 0.16), *t* (36) = -1.13, *p* > .05. However, analysis of reaction times to correct responses demonstrated that participants in the advanced facilitation condition (*M* = 1257.40; *SD* = 336.39) were faster to recognize words from the text implying forward movements relative to participants in the control condition (*M* = 1571.75; *SD* = 555.01), *t* (27,418) = 2.14, *p* = .024 (one-tailed), *r* = .38 (see Figure 5.4).

Words from the text that do not imply any movements. An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.69; *SD* = 0.29) did not differ significantly in their answers from participants in the advanced facilitation condition (*M* = 0.78; *SD* = 0.29), *t* (36) = -0.86, $p > .05$. Similarly, analysis of reaction times to correct responses revealed that participants in the advanced facilitation condition (*M* = 1332.89; *SD* = 290.97) did not differ significantly in their responses from participants in the control condition (*M* = 1473.94; *SD* = 301.39), *t* (34) = 1.43, $p > .05$ (see Figure 5.4).

Words of movement not mentioned in the text (false alarm words). An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.66; *SD* = 0.24) did not differ significantly in their answers from participants in the advanced facilitation condition (*M* = 0.59; *SD* = 0.23), *t* (36) = 0.87, $p > .05$. Moreover, analysis of reaction times to correct responses revealed that participants in the advanced facilitation condition (*M* = 1393.66; *SD* = 388.13) did not differ significantly in their responses from participants in the control condition (*M* = 1554.81; *SD* = 418.83), *t* (35) = 1.22, $p > .05$ (see Figure 5.4).

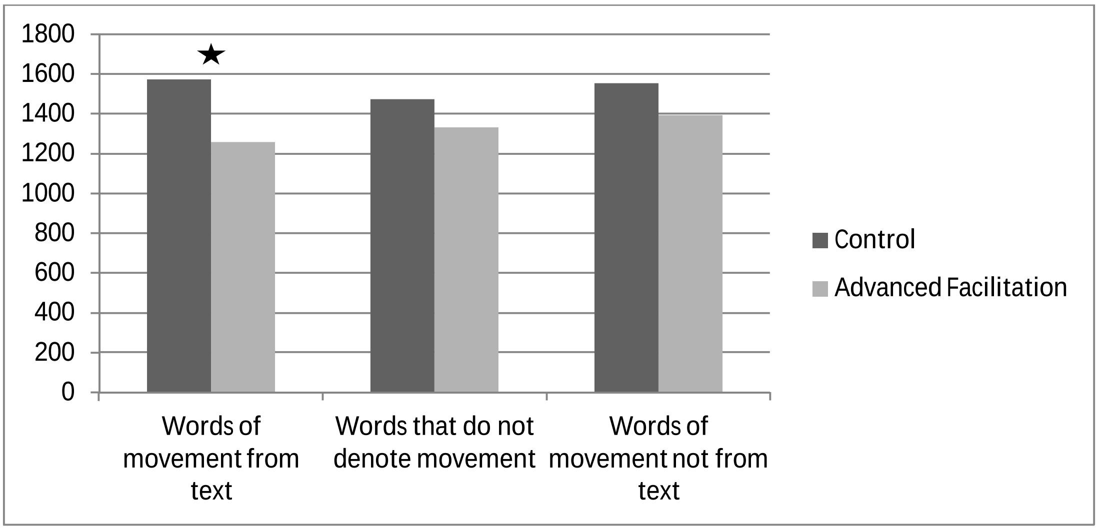

Figure 5.4. Recognition times (reported in milliseconds) of participants in the control and advanced facilitation conditions (Experiment 4). The star corresponds to significant pairwise comparisons ($p < .05$).

5.3.3. Discussion

In summary, Experiment 4 assessed whether matching body movement and matching body posture could facilitate discourse processing. Consistent with simulation theory, participants whose motor system was manipulated to be congruent with the discourse meaning (a) showed higher accuracy in their responses with regard to implicit comprehension measure in a judgment task and (b) responded faster with regard to explicit comprehension measure in a recognition task and implicit comprehension measure in a judgment task. Additionally, there was a fragile effect of matching action on the speed with which participants read some paragraphs of text. Contrary to hypothesis, explicit comprehension was not strongly influenced by manipulation of the motor state. More precisely, results revealed that explicit comprehension performance of participants in the advanced facilitation condition did not differ significantly from explicit comprehension performance of participants in the control condition regarding both accuracy and response times in a judgment task. That is, reported findings seem to suggest that simulation system contributed more to implicit comprehension of discourse based on deduction and interpretation and less (or equally with linguistic system) to shallow explicit comprehension.

5.4. Experiment 5

Experiment 5 investigated whether mere adoption of body posture appropriate for the metaphorical phrases would facilitate discourse processing to the same extent as engaging in literal movement prior to text reading (as reported in Experiment 4). Such a prediction is in harmony with previous experimental findings that showed the activation of motor cortex during motor imagery, motor preparation, motor performance (Deceti et al., 1994) and passive observation of various video sequences about action (e.g., Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995).

5.4.1. Method

5.4.1.1. Participants and design

The sample consisted of 37 (36 right-handed, one left-handed), native Portuguese-speaking university students (M_{age} = 22.86, SD_{age} = 5.59). 14 participants were male (M_{age} = 24.43; SD_{age} = 6.50), 21 were female (M_{age} = 21.71; SD_{age} = 4.97), and two participants did not indicate gender. The experiment was a single factor between-participants design. Participants were randomly assigned to one of the conditions: basic facilitation or control condition.

5.4.1.2. Materials and procedure

The materials were strictly identical to those for Experiment 4. The procedure was nearly identical to that in Experiment 4, with the exception that participants in the basic facilitation condition did not exercise on a bike prior to text reading.

5.4.2. Results

5.4.2.1. Coding of Variables and Preliminary analyses

Accuracy rate was calculated on the number of correct answers to target variables by coding incorrect response as “0” and correct response as “1”. Preliminary analyses showed that there was a significant effect of gender on target text reading time after controlling for the effect of tutorial reading time, F (1, 32) = 4.86, p =.035. At the same time, follow-up analysis investigating the effect of gender on the speed with which participants read paragraphs of text revealed that this effect was non-significant, F (7, 26) = 1.49, p = .21, thus suggesting that gender variable did not significantly alter the direction or strength of the relationship between a predictor and an outcome. Similarly, by classifying age into the three groups (18-29, 30-49, 50+), it was revealed that there was no significant effect of age on target text reading time after controlling for the effect of tutorial reading time, F (1, 34) = 0.48, p > .05. Finally, post-experimental interview confirmed that none of the participants suspected the purpose of lead leg manipulation.

5.4.2.2. Measures of "online" discourse comprehension

Target text reading time

An 8 (Paragraphs 1 to 8) within factor x 2 (condition: control *vs.* basic facilitation) between factor mixed ANOVA, with tutorial reading time as a covariate, was conducted to analyze the reading times of the target text. Because tutorial and target texts were identical in size, tutorial reading time was chosen as a covariate in order to control for individual differences in reading time. Results showed that tutorial reading time (reported in milliseconds) was significantly related to the participant's target text reading time, F (1, 34) = 75.05, p < .001, partial η^2 = .69. However, there was no effect of matching action on target text reading time after controlling for the effect of the tutorial reading time, F (1, 34) = 0.69, p =.686, partial η^2 = .005. Considering that the one-way analysis of variance (ANOVA) is not significant, and therefore does not protect against inflated Type I error rates in subsequent analyses of data, planned contrasts are not reported (Howell, 2006). Estimated marginal reading time means of participants from both conditions are provided in Table 5.7.

Table 5.7

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 5

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	20477.07	685.52	19083.93	21870.21
Basic Facilitation	20887.43	705.18	19454.32	22320.53

Using Pillai's trace, it was revealed that there was also no effect of matching action on the speed with which participants read paragraphs of text, F (6, 29) = 0.66, p = .68, η^2 = 121. Considering that the multivariate analysis of variance (MANOVA) is not significant, and therefore does not protect against inflated Type I error rates in follow-up a-priori comparisons, planned contrasts are not reported (Bock, 1975) At the same time, a non-significant MANOVA does not allow to fully understand how comprehension proceeded throughout the text. Therefore, MANOVA was followed with separate ANOVAs on each of the dependent variables. To control for the inflation of familywise error rate, a Bonferroni correction was applied to the subsequent ANOVAs (Harris, 1975). The results of univariate test statistics, however, revealed that participants did not significantly differ, nor approached significance in their reading of each of the paragraphs of the target text (see Figure 5.5 and Table 5.8). For the mean differences and exact *p*-values, see Table 5.9.

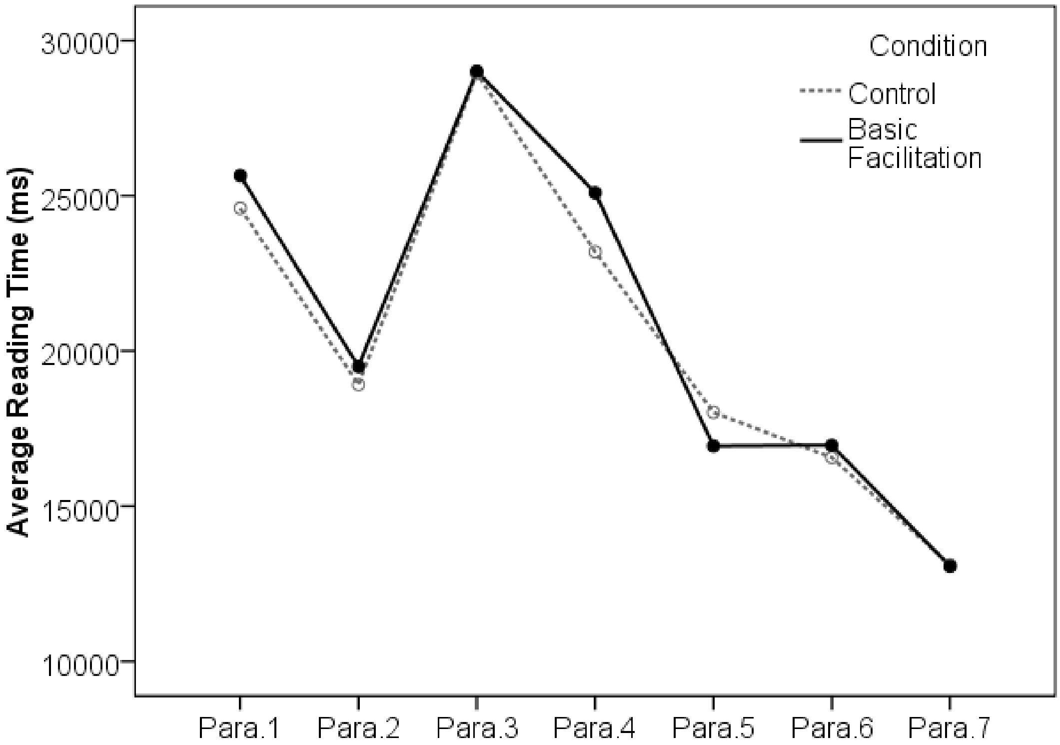

Figure 5.5. Mean reading times in milliseconds (estimated marginal means) for seven paragraphs of the target text according to condition (control *vs.* advanced facilitation) in Experiment 5.

Table 5.8

Estimated Marginal Reading Time Means in Milliseconds and their 95% Confidence Intervals for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 5

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Control	24599.18	1134.37	22293.86	26904.50
	BF	25650.20	1166.91	23278.75	28021.64
2	Control	18912.07	778.68	17329.61	20494.54
	BF	19498.15	801.02	17870.29	21126.01
3	Control	28939.02	840.11	27231.70	30646.34
	BF	29009.01	864.21	27252.72	30765.30
4	BF	23193.14	1574.82	19992.72	26393.57
	BF	25098.09	1619.99	21805.86	28390.31
5	Control	18023.10	703.24	16593.95	19452.26
	BF	16938.87	723.41	15468.72	18409.02
6	BF	16567.42	1011.47	14511.87	18622.98
	BF	16958.44	1040.48	14843.92	19072.96
7	Control	13105.54	789.05	11502.00	14709.07
	BF	13059.23	811.68	11409.70	14708.76

Note: Abbreviation “BF” refers to “Basic Facilitation”

Table 5.9

Pairwise Comparisons Based on Estimated Marginal Means with 95 % Confidence Intervals for Difference for Each Paragraph of the Target Text According to Condition with Tutorial Mean Reading Time as a Covariate in Experiment 5

Para.	(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
1	Control	BF	-1051.02	1664.53	.532	-4433.75	2331.72
	BF	Control	1051.02	1664.53	.532	-2331.72	4433.75
2	Control	BF	-586.08	1142.60	.611	-2908.13	1735.97
	BF	Control	586.08	1142.60	.611	-1735.97	2908.13
3	Control	BF	-69.99	1232.75	.955	-2575.24	2435.26
	BF	Control	69.99	1232.75	.955	-2435.26	2575.24
4	Control	BF	-1904.94	2310.83	.415	-6601.11	2791.23
	BF	Control	1904.94	2310.83	.415	-2791.23	6601.11
5	Control	BF	1084.23	1031.91	.301	-1012.86	3181.32
	BF	Control	-1084.23	1031.91	.301	-3181.32	1012.86
6	Control	BF	-391.02	1484.19	.794	-3407.26	2625.22
	BF	Control	391.02	1484.19	.794	-2625.22	3407.26
7	Control	BF	46.31	1157.82	.968	-2306.65	2399.27
	BF	Control	-46.31	1157.82	.968	-2399.27	2306.65

Note: Abbreviation “BF” refers to “Basic Facilitation”. A letter “a” refers to adjustment for multiple comparisons: Bonferroni.

5.4.2.3. Measures of "offline" discourse comprehension

Judgment task

Explicit comprehension

An independent-samples t-test on the number of correct responses to sentences checking explicit comprehension of events from text revealed that participants in the control condition (M = 0.84; SD = 0.37) did not differ significantly in their answers from participants in the basic facilitation condition (M = 0.92; SD = 0.19), t (35) = -0.76, p >.05. However, analysis of reaction times revealed that participants in the basic facilitation condition (M = 3316.02; SD = 460.92) were faster to decide whether sentences were correct relative to participants in the control condition (M = 4113.50; SD = 887.87), t (20,16) = 3.14, p = .003 (one-tailed), r = .59 (see Figure 5.6).

Implicit comprehension

An independent-samples t-test on the number of correct responses to sentences checking implicit comprehension of events from text revealed that participants in the basic facilitation condition (M = 0.89; SD = 0.27) provided significantly more correct answers comparing to participants in the control condition (M = 0.61; SD = 0.40), t (29.91) = -2.41, p = .011 (one-tailed), r = .40. Moreover, analysis of reaction times revealed that participants in the basic facilitation condition (M = 2389.05; SD = 556.78) were significantly faster to decide whether sentences were correct relative to participants in the control condition (M = 2880.28; SD = 895.63), t (29) = 1.87, p = .036 (one-tailed), r = .33 (see Figure 5.6).

Control measure

An independent-samples t-test on the number of correct responses to incorrect sentences with regard to the content of the text revealed that participants in the control condition (M = 0.58; SD = 0.43) did not differ significantly in their answers from participants in the basic facilitation condition (M = 0.78; SD = 0.26), t (34) = -

1.65, *p* >.05. Similarly, analysis of reaction times revealed that participants in the basic facilitation condition (*M* = 4290.14; *SD* = 1048.72) did not differ significantly in their responses from participants in the control condition (*M* = 5026.04; *SD* = 3325.08), *t* (13,74) = 0.77, *p* >.05 (see Figure 5.6).

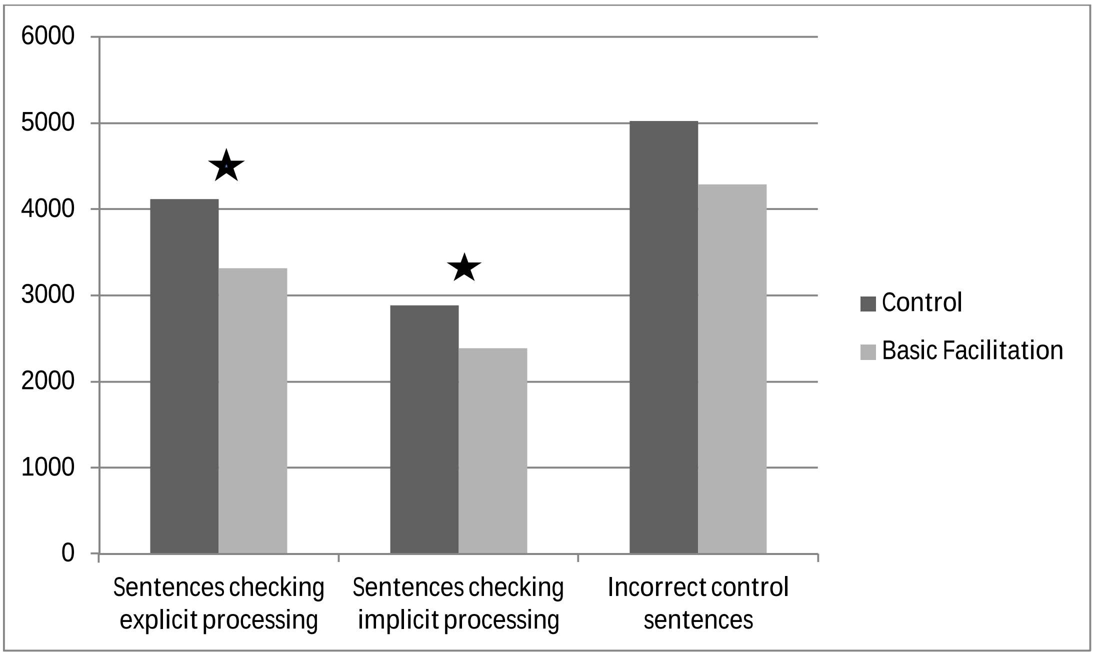

Figure 5.6. Judgment times (reported in milliseconds) of participants in the control and basic facilitation conditions (Experiment 5). The stars correspond to significant pairwise comparisons ($p < .05$).

Recognition task

Explicit comprehension

Words from the text implying forward movements (parts of metaphorical phrases). An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.64; *SD* = 0.21) did not differ significantly in their answers from participants in the basic facilitation condition (*M* = 0.60; *SD* = 0.24), *t* (35) = 0.52, *p* >.05. However, analysis of reaction times to correct responses demonstrated that participants in the basic facilitation condition (*M* = 1278.08; *SD* = 418.90) were faster to recognize words from the text implying forward movements relative to participants in the control condition (*M* = 1571.75; *SD* = 555.01), *t* (35) = 1.79, *p* = .041 (one-tailed), *r* = .29 (see Figure 5.7).

Words from the text that do not imply any movement. An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.71; *SD* = 0.29) did not differ significantly in their answers from participants in the basic facilitation condition (*M* = 0.79; *SD* = 0.22), *t* (35) = -0.91, *p* >.05. Similarly, analysis of reaction times to correct responses revealed that participants in the basic facilitation condition (*M* = 1342.13; *SD* = 373.81) did not differ significantly in their responses relative to participants in the control condition (*M* = 1442.17; *SD* = 321.96), *t* (34) = 0.86, *p* >.05 (see Figure 5.7).

Words of movement not mentioned in the text (false alarm words). An independent-samples t-test on the number of correct responses revealed that participants in the control condition (*M* = 0.65; *SD* = 0.23) did not differ significantly in their answers from participants in the basic facilitation condition (*M* = 0.60; *SD* = 0.26), *t* (35) = 0.66, *p* >.05. Similarly, analysis of reaction times to incorrect responses revealed that participants in the basic facilitation condition (*M* = 1421.23; *SD* = 350.06) did not differ significantly in their responses relative to participants in the control condition (*M* = 1519.21; *SD* = 435.60), *t* (35) = 0.75, *p* >.05 (see Figure 5.7).

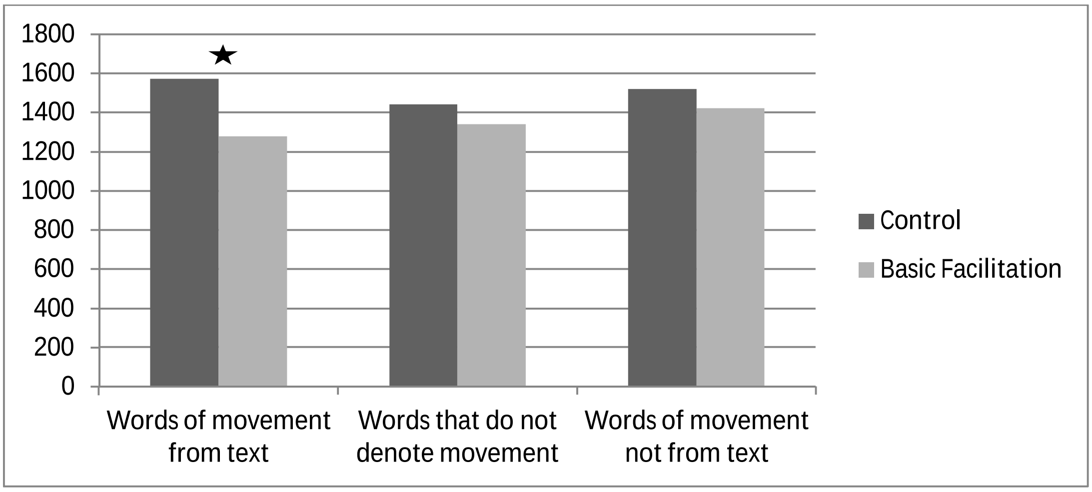

Figure 5.7. Recognition times (reported in milliseconds) of participants in the control and basic facilitation conditions (Experiment 5). The star corresponds to significant pairwise comparisons (*p* < .05).

5.4.3. Discussion

The present experiment was designed to test whether mere preparation of the body for movement would affect discourse processing. The findings of this experiment consistently replicate the findings of Experiment 4 in showing the effect of matching action state on implicit discourse comprehension regarding both accuracy and response times, and explicit comprehension regarding response times in a recognition task. Similarly, like in Experiment 4, a matching action state did not have any effect on accuracy with regard to explicit comprehension measure in both recognition and judgment tasks. The differences between two studies are as follows. First, there was no effect of matching state on target text reading time, compared to Experiment 4. Second, there was a significant effect of matching action state on the speed with which participants judged explicit sentences as correct or incorrect with respect to text's content, compared to Experiment 4. These results reinforce the idea that matching action state had more influence on implicit comprehension than on explicit comprehension.

5.5. General discussion

In two experiments the role of action simulation in comprehension of discourse was investigated. After reading a text that described a protagonist making metaphorical forward movements, participants were faster in their judgment times with regard to implicit comprehension questions (Experiment 4 and 5) and explicit comprehension questions (Experiment 5) when their bodily systems were prepared for processing of action-congruent information. Also, participants whose bodily systems were manipulated to be congruent with the discourse meaning were faster to recognize target words related to metaphorical phrases of movement from the text. Finally, the effect of matching action state on "online" target text reading time ("online" processing) was fragile, being found only for paragraphs 3 and 6 in Experiment 4. The effect of action body systems on implicit discourse processing was by far the strongest among all effects reported in this paper, given that participants differed significantly not only on response times, but as well on the number of correct answers (accuracy) they provided to measures testing implicit comprehension of events from discourse. These findings support the hypothesis that understanding of language involves constructing a sensorimotor simulation of the described event and add to the growing body of evidence that action simulation is involved in comprehension (e.g., Glenberg & Kaschak, 2002; Taylor & Zwaan, 2008; Wilson & Gibbs, 2007; Zwaan & Taylor, 2006). However, current research advances beyond the previous findings by demonstrating that matching action state appears to affect comprehension not only at lexical (e.g., Hauk et al., 2004) and sentential levels (e.g., Glenberg & Kaschak, 2002), but as well at the level of discourse.

The reported results are consistent with converging evidence from neuroscience on neural substrates of discourse comprehension and share the view that action states can affect processing at a more global discourse level. For example, Speer, Reynolds, Swallow, and Zacks (2009) used functional magnetic resonance imaging (fMRI) and asked participants to read four narratives from the book One Boy's Day (Barker & Wright, 1951) which described the everyday activities (e.g., waking up, playing before school, class work, music lesson) of a 7-year-old boy Raymond. Later, readers' comprehension was tested on the following events: characters and goals, interactions with objects, space, and time. Among other findings, it was revealed that adjacent and overlapping regions in bilateral posterior superior temporal cortex (Brodmann's area, BA, 22/39) increased in activation when participants observed goal-directed, intentional actions, relative to non-goal-directed actions. Within this framework, similar guiding for action simulation might have occurred for present study, given that metaphorical phrases in our text described goal-directed actions that needed to be taken to build a Great Society which a protagonist of the story describes.

It is interesting to note that the strongest results in the present research were obtained for measures checking implicit comprehension of discourse. More concretely, it was found that participants in the advanced and basic facilitation conditions (Experiments 4 and 5) differed both on accuracy and response times from participants in the control conditions. Impressively, these differences on accuracy and response times represented a medium-sized effect in both experiments (all $r > .30$), providing support for the conclusion that the influence of action simulation is strong for comprehension of information that involves deduction and interpretation.

One possible explanation for why individuals rely to a lesser extent on simulation while answering explicit questions is offered by Barsalou et al.'s (2008) language and situated simulation (LASS) theory. The LASS theory proposes that language understanding relies both on linguistic processing and situated simulation. Linguistic system is responsible for processing of linguistic forms and simulation system is responsible for generation of linguistic meanings. Consequently, when linguistic processing dominates, people tend to build shallow meaningful representations derived from linguistic forms rather than linguistic meanings. Conversely, when simulation system dominates, people tend to build comprehensive mental representations from inferences (information that goes beyond information mentioned explicitly) computed during processing of discourse. Finally, this theory postulates that the type of processing relies heavily on task conditions. More concretely, in shallow processing tasks comprehension may primarily depend on linguistic processing rather than on simulation, and in deeper processing tasks comprehension may rely more on simulation than on linguistic processing. Moreover, under many conditions in deeper processing tasks comprehension may rely heavily on both systems – linguistic and simulation.

Clearly, if linguistic system only processes linguistic forms and word associations (not linguistic meanings), then it can hardly explain how comprehenders recognize implicit facts. Accordingly, it is reasonable to conclude that present results regarding implicit comprehension of discourse are compatible with the hypothesis that the LASS theory advocates: simulation system prevails under the conditions when individuals compute a wide variety of inferences, and thus process information deeply.

Regarding the results on explicit comprehension measure, reported findings should be regarded with caution. On the one hand, it is worth noting that there was an effect of matching action state on recognition (Experiments 4 and 5) and judgment times (Experiment 5), and thus it cannot be easily concluded that simulation system did not underlie explicit discourse comprehension. On the other hand, the absence of any effect on accuracy (Experiments 4 and 5) for both recognition and judgment tasks as well as the absence of any effect on judgment times (Experiment 4) suggests that the effect of matching action state on explicit information was fragile. Thus, the LASS theory might presumably account for the current results in suggesting that explicit understanding of discourse relied heavily on different mixtures of linguistic and simulation systems. Nevertheless, definite answers to how much action simulation affects explicit discourse processing must await further empirical investigation.

In summary, two experiments presented here were designed to test whether simulation of metaphorical actions facilitates discourse comprehension. It was found that engaging in literal action and merely preparing the body for action has a strong influence on offline discourse comprehension. Moreover, our findings lend support for LASS theory of conceptual processing (Barsalou et al., 2008) in showing that simulation system is more powerful in discourse comprehension when individuals process implicit information rather than explicit information. Finally, the reported findings contribute to a better understanding how simulation affects more global discourse level of processing and extend the previous literature on effects of simulation on memory (e.g., Pecher, Zanolie, & Zeelenberg, 2007; Pecher et al., 2009) and metaphor comprehension (e.g., Wilson & Gibbs, 2007).

CHAPTER 6

Conclusions

Abstract

This part of the thesis presents a summary of the main part of the text as well as deduction made on the basis of reported findings. Additionally, limitations of research are discussed as well as implications of the work for future research.

6.1. Summary of results

A key suggestion of symbolic theories is that language comprehension arises from manipulation of amodal symbols that redescribe perceptual, motor, and emotional states. This suggestion seems at odds with our ability to interact with the environment. For example, it is difficult to think that sensory systems of the body are not involved in language processing when one describes his last visit to a coffee shop like Starbucks or Tim Hortons with the following words: aromatic, delectable, luscious, scrumptious, fragrant, warm, cozy, comforting, entrancing, piquant, or sensual. In contrast to symbolic theories, an embodied approach to language comprehension holds that amodal symbols become meaningful only via our perception and interaction with objects, and situations these objects denote (Glenberg, 2010). Thus, language processing involves neural and bodily systems used in real world perceptual, action, and emotional experiences. Under this conceptualization, understanding a sentence such as “The waitress looks amused when she passes a cup of freshly ground coffee and a scone to a middle-aged man” requires the retrieval of perceptual information to simulate the objects and agents described in the sentence (e.g, coffee, middle-aged man), olfactory perceptual information to simulate the smell of a warm scone and freshly ground coffee, motor information to simulate how the waitress passes the coffee to a man, and emotional information to simulate the amused state of the waitress.

In this thesis the discussion of the importance of sensorimotor activation that occurs during language comprehension began with a review of empirical studies from research on processing of language describing concrete and abstract concepts. It was found that the data from all these studies converge on the conclusion that embodied representations are necessary for comprehension. At the same time, it was noted that significant issues in the domain of language processing still remain to be addressed. Chief among them are the following two questions. The first question is whether embodiment affects comprehension of extended linguistic events such as discourse. Interest for this question is inspired by previous discussions on the paucity of research regarding the role of modality-specific simulations during discourse understanding (Fischer & Zwaan, 2008) as well as the importance of testing language comprehension on a more global discourse level (Graesser et al., 1997; Sparks &

Rapp, 2010). The second question is whether embodied representations serve to affect “offline” discourse processing.

After reviewing empirical and theoretical evidence in support of embodied cognition as well as discussing the usefulness of modality-specific simulations for language comprehension, the aforementioned two questions were empirically investigated in five experiments. Experiments 1 and 2 examined the influence of emotional state (positive, neutral control, negative) on “online” (reading time, imagery vividness, perceived reading ease, feelings of presence) and “offline” (verbatim and inference questions) measures of discourse comprehension. Those participants whose facial postures were manipulated to be congruent (“pen in the teeth” matching condition) with the positive valence of the text generally showed faster reading times and higher perceived reading ease relative to those whose facial postures were incongruent (“pen in the lips” mismatching condition) or neutral (without a manipulation). No other measures showed an effect of emotional state. These results are consistent with previous findings where sentence stimuli were used (e.g., Havas et al., 2007) and support embodied theories of cognition in which abstract symbols are grounded in sensorimotor systems (Barsalou, 1999a; Glenberg, 1997; Zwaan, 2004). Perhaps most importantly, the reported findings indicate that a matching emotional state appears to affect “online” comprehension not only at lexical and sentential levels, but as well at the level of discourse.

Whereas Experiment 2 assessed whether modality-specific simulations capture explicit information connoted by the language, Experiment 3 assessed whether modality-specific simulations capture implicit information that goes beyond words mentioned in the text. Participants were recruited to read a narrative text describing scenes that implicitly suggested a particular position in space of a person or an entity while their body was turned 90 degrees to the right (matching condition) or 90 degrees to the left (mismatching condition), or in a normal condition without a manipulation of body direction (neutral condition). Participants’ comprehension was assessed with “online” (reading times, vividness of mental imagery, vividness of specific mental, imagery, spatial presence) and “offline” (sequencing task) comprehension measures. The results showed that those who read the text in the matching condition reported higher degree of vividness of mental imagery, but only with regard to scenes that described movements involving two persons in the left spatial dimension. No other measures showed an effect of congruent body direction on discourse processing. Therefore, it can be concluded that even implicit properties of simulations, such as spatial dimension or location, are at least somewhat involved in processing of large language segments such as discourse.

Finally, Experiments 4 and 5 were conducted to demonstrate that engaging in real action (by exercising on a stationary bike) or merely preparing the motor system for action (by reading the text with the lead leg advanced forward) affects how individuals comprehend discourse describing metaphorical movements. Participants read a text describing forward metaphorical movements (e.g., pursue a better future) while their bodily systems were either prepared (facilitation condition) or not prepared (control) for processing of action-congruent information. Participants' understanding of discourse was assessed with "online" (reading times) and "offline" (accuracy, recognition times, judgment times) comprehension measures. It was found that action simulation affected "offline" implicit comprehension of discourse more than "offline" explicit comprehension. "Online" discourse comprehension did not seem to be considerably affected by action simulation. The reported findings are consistent with language and situated simulation theory (Barsalou et al., 2008) which predicts that simulation system affects to a greater extent comprehensive processing of information based on deduction and interpretation, and to a lesser extent shallow processing based on information explicitly provided in the text. These findings advance beyond Experiments 1 to 3 by demonstrating that modality-specific simulations are involved even in comprehension of discourse describing metaphorical actions that are physically impossible to perform.

In sum, the reported findings support embodied cognition suggesting that sensorimotor and affective states are implicated, at least partially, in "online" and "offline" discourse processing. Clearly, the experiments reported in this thesis do not provide evidence that no amodal representations get activated during language processing, but they do provide evidence that sensorimotor grounding is necessary for comprehension of large language segments such as discourse.

6.2. Limitations of research

Clearly, the evidence presented in experiments 1 to 5 supports the view that language needs to be grounded, at least partially, to become meaningful. However, the great body of evidence in support of the important role of interrelations between words in a language (e.g., Lund, Burgess, & Atchley, 1995; Burgess & Lund, 1997; Landauer & Dumais, 1997; Landauer et al., 1998) is also found to be convincing. How do we reconcile these approaches? Unfortunately, this appears to be impossible as the problem regarding the activation of symbolic and embodied representations during language comprehension is to be found in a methodological approach. Specifically, it is fair to say that most of the symbolic psycholinguistic experiments considered the contribution of amodal symbols to comprehension to the exclusion of potential embodied representations. Similarly, the experiments reported in this thesis were designed to demonstrate the activation of embodied representations during discourse comprehension rather than disprove the activation of symbolic representations. Therefore, the findings of this thesis do not validate the claim that language is entirely embodied. So much evidence exists now in support of both linguistic co-occurrence and simulation during language processing that it seems reasonable to assume that comprehension arises from combination of both embodied and symbolic aspects of cognition rather than from one source alone

Nonetheless, the provided empirical evidence suggesting that modality-specific simulations can affect “online” and “offline” processing of large language segments such as discourse does not allow for simulations as a by-product of language comprehension. Similarly, the provided evidence on comprehension of abstract metaphorical movements (Chapter 5) does suggest that the problem of abstract concepts can be accommodated by an embodied approach. It is true that the results of Experiments 4 and 5 do not provide an explanation how all abstract concepts are grounded. However, the success of projects like these might be useful as psychologists continue to tackle the problem of abstraction and offer new approaches to comprehension of concepts that are not highly imageable. Finally, the reviewed evidence (Chapter 2) on the importance of situated action for cognition (see a study of Glenberg & Robertson, 2000) also makes it hard to believe that the role of embodiment in language processing is epiphenomenal.

The most general conclusion that can be made in this context is that future research should seek to define the limitations of the power of sensory-motor grounding and amodal symbols in language comprehension. More concretely, the current state of affairs in the field suggests that new research questions could be raised. These include at what point in comprehension and under what conditions language and simulation systems get activated, and under what circumstances (nature of linguistic or non-linguistic stimuli, easiness of the text, etc.) symbolic or embodied representations prevail in comprehension tasks.

6.3. Avenues for future research

The findings reported in this research offer a few possibilities to advance progressively a future research program in the domain of "embodied" language processing by modifications of the methods being used and introduction of new ideas.

First, regarding the role of emotion simulation in understanding of discourse, it was demonstrated that comprehenders simulate positive events during "online" discourse comprehension. However, it would be very interesting to find out if comprehension of discourse describing sad or angry events also requires the resources of simulation system. To assess this prediction, a similar experiment as described in Chapter 3 could be run, but with a negative text condition. If a strong embodiment hypothesis is correct, then participants who read and process the text in the "pen in the lips" (simulating frown) condition should demonstrate faster reading speeds relative to participants who read and process the text in the "pen in the teeth" (simulating smile) condition or neutral (control) condition without a pen. This methodology will allow to test whether the results using extended language segments (texts) would dissociate from the results on sentence processing gathered from a negative text condition (see experiments of Havas et al., 2007).

Second, with regard to the role of perceptual simulation in comprehension of discourse events that implicitly suggest a particular spatial dimension to an entity or a person, self-paced reading times could be substituted with other "online" measures of comprehension that could provide additional clarity for the effect of congruent direction on measures of mental imagery reported in Chapter 4. Such "online" measures could include collection of reading times immediately after each sentence of the text (see Graesser et al., 1997, for a discussion of “online” measures that interrupt the comprehension process) or, perhaps more promising, recording gaze durations. If one chooses to record gaze durations, the manipulation of body direction is no longer needed, and thus helps resolve the issue of integratability of the body direction into the simulation constructed of the content of discourse (see Section 4.3). More specifically, if people mentally represent implied perceptual features, then their eye movements should be used to coordinate elements of situational model with elements of visual scene. That is, if people read a sentence like “He stopped a car and went out to smoke a cigarette”, then their eye movements should “follow” the direction of movement (i.e., leaving a car suggests a horizontal left direction of eye movements) of the person described in the story. Similarly, if people read a sentence like “The wedding ring on his finger reminded him of his wife”, then their eye movements should be directed to the fourth finger of the left hand (i.e., looking or imagining looking at your wedding ring suggests a vertical left direction of eye movements).

In fact, there are good reasons to think that this methodology could potentially be quite useful. For instance, using the eye-tracking device, Spivey and Geng (2001) found that participants’ eye movements were congruent with the direction of movements (e.g., left vs. right) described in the stories like the ones presented below. Importantly, however, Spivey and Geng’s (2001) stories explicitly suggested a particular location to an object, but not implicitly.

> LEFT STORY – Imagine a train extending outward to the left. It is pointed to the right, and you are facing the side of the engine. It is not moving. Five cars down is a cargo holder with pink graffiti sprayed on its side. Another six cars down is a flat car. The train begins to move. Further down the train you see the caboose coming around a corner.
>
> RIGHT STORY – Imaging a fishing boat floating in the ocean. It’s facing leftward from your perspective. At the back of the boat is a fisherman with a fishing pole. The pole extends about 10 feet to the right beyond the edge of the boat. And from the end of the pole, the fishing line extends another 50 feet off to the right before finally dipping into the water.

Alternatively, by using sentence stimuli, a simulation of locations could be investigated by using an experimental procedure similar to that offered by Stanfield and Zwaan (2001). In their experiment, participants were presented with sentences describing objects or animals in particular orientations. After reading the sentence, participants were presented with a picture of the object or animal that the sentence described. The task consisted in judging whether the object (animal) was mentioned in the sentence. The major result was that response latencies were faster when the orientation of an object on the picture matched that implied by a sentence description. In brief, a similar research method could be applied to test a hypothesis that people mentally represent a location in which a person or an entity is present. More specifically, verification times for a picture of a man by the driver's door of the car should be shorter than verification times for a picture of a man by the passenger's door of the car after reading the sentence "John stopped the car and went to the bar". Conversely, verification times for a picture of a man by the passenger's door of the car should be shorter than verification times for a picture of a man by the passenger's door of the car after reading the sentence "Bob asked John to stop and went to the bar".

Another question that warrants research concerns "offline" discourse comprehension. The results of experiments 1 to 3 demonstrate no effect of simulation on "offline" processing. At the same time, the results of experiments 4 and 5 provide strong support for involvement of embodied representations in "offline" understanding of discourse. Importantly, however, the methods of assessing discourse comprehension in these experiments were quite different. Whereas in experiments 1 to 3 standardized reading assessments were used (e.g., open questions, inference questions, etc.), in experiments 4 and 5 response times were collected to detect an effect of simulation on "offline" discourse comprehension. Therefore, one way to reconcile these findings is to use the same comprehension measure, such as response times at test, in all three experiments. It is worth pointing out in this context that the use of different comprehension methods in the current research was justifiable and theoretically sound, given the observed non-significance in standardized measures of "offline" comprehension. Explorations like these are critical to understand what comprehension measures are most suitable and sensitive in future prospective experimental studies.

A promising area for future research is in investigating under what conditions simulation system prevails in comprehension of text. The findings reported in Experiment 4 and 5 made a novel contribution to the literature by showing that simulation system affects to a greater extent comprehensive processing of information based on deduction and interpretation, and to a lesser extent shallow processing based on information explicitly provided in the text. Importantly, these results were obtained using textually explicit and implicit statements (see Pearson & Johnson, 1980) and the following comprehension measures: recognition times, judgments times, and accuracy. While these findings support the LASS theory of conceptual processing (Barsalou et al., 2008), they are still limited to specific domain (in this case action simulation), and thus does not allow to advocate generalizable consequences of embodiment during comprehension of explicit and implicit information with regard to other domains, such as perception or emotion. In brief, to progress on this issue, similar explicit and implicit statements, either correct or incorrect with regard to text's content, should be used in other experiments reported in this thesis (or similar to the ones that have been reported).

Finally, a related, though distinct, promising area for future research is in investigating whether embodiment manipulations may help in learning a new foreign language. As an example of one such manipulation, consider the "Moved by Reading" technique proposed by Glenberg and associates (see Glenberg, 2011, for discussion). A key suggestion of this technique is that emerging readers have to learn how to index words and phrases to their embodied experiences. Having children manipulate toys on the computer to correspond to what they are reading, Glenberg, Willford, Gibson, Goldberg, and Zhu (2011) showed that physical and imaginative manipulation of the toys benefits both short-term- and long-term reading comprehension of children. Thus, it is reasonable to assume that a similar manipulation strategy might also facilitate foreign language learning. More specifically, this technique can be tested on Erasmus Mundus students who start learning Portuguese by asking them to read phrases or short sentences and act out the meaning of the phrase (sentence) using objects or actually performing different actions described by the sentence (see also Wilson & Gibbs, 2007, for a discussion). In a week, participants' memory for the phrases or individual words can be tested and compared with the memory for the phrases of participants who did not undergo a manipulation. Of course, such an experiment has one important limitation: embodied manipulations may be used with regard to concrete, but not abstract concepts. At the same time, considering that the supporters of embodied view of cognition have partially tackled the problem of abstraction and are likely to progress on this issue in the future, such an experiment could be quite useful to foster further research activity in this new field.

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Annexes

Annex A

Summary of Empirical Studies on Contribution of Perceptual, Action, and Emotion Systems to Language Comprehension

******Contribution of Perceptual Systems******

Fincher-Kiefer (2001)	
Independent variables	Study 1: • Type of memory load (low vs. high imagery sentences) • Sentence type (constant vs. inconsistent) Study 2: • Type of memory load (four or six item letter string vs. box matrix containing three or five dots) • Sentence type (constant vs. inconsistent)
Dependant variables	Study 1 and 2: • Situation model generation • Text comprehension
Data collection	• Recall protocols • Reading times
Major result	Visual memory load impaired text comprehension, and thus it can be concluded that perceptual simulations are implicated in processing of language

Pecher, Dantzig, Zwaan, and Zeelenberg (2009)	
Independent variables	• Sentences implying orientation or shape • Picture condition (match vs. mismatch with the sentence meaning) • Sentence presentation (immediately vs. long delay)
Dependant variables	• Online and offline sentence processing
Data collection	• Delayed picture recognition task
Major result	Recognition performance was better if the picture matched the implied shape or orientation of the object in an earlier sentence both when participants responded immediately after reading the sentences and when sentence reading and picture recognition were separated in time (45-min delay).

Richardson, Spivey, Barsalou, and McRae (2003)	
Independent variables	Study 1 and 2: • Orientation of visual stimuli (horizontal vs. vertical) • Verb image schema (horizontal vs. vertical)
Dependant variables	Study 1: • Performance on a visual discrimination task Study 2: • Performance on a memory task

(continued)

Data collection	• Reaction times
Major result	Spatial orientation of the verb's image schema impaired performance of a visual discrimination task, but facilitated performance on a visual memory task. This suggests that comprehension of verbs is closely tied to visuospatial simulations of experience in the modality-specific systems
Spivey and Geng (2001)	
Independent variables	Study 1: • Direction of scene description (upward, downward, leftward, rightward, control) Study 2: • Position of objects on a screen (upward, downward, leftward, rightward) • Color of the object • Direction of tilt of the object
Dependent variables	Study 1 and 2: • Position of eye movements
Data collection	• Eye-tracking
Major result	Participants' eye movements were consistent with the position of objects and direction implied by scene descriptions. This suggests that the same bodily systems used in control of perceptual-motor mechanisms were used while participants were viewing, imagining, and remembering elements of the described scene and picture location
Stanfield and Zwaan (2001)	
Independent variables	• Sentences implying orientation • Picture orientation condition (match vs. mismatch with the orientation implied by the sentence)
Dependent variables	• Sentence comprehension
Data collection	• Reaction times
Major result	Sentence processing was facilitated when picture stimuli matched orientation implied by the sentence
Zwaan, Madden, Yaxley, and Aveyard (2004)	
Independent variables	• Sentences implying motion • Visual motion condition (match vs. mismatch with the motion implied by the sentence)
Dependent variables	• Sentence comprehension
Data collection	• Reaction times

(continued)

Major result	Sentence processing was facilitated when the motion of the picture sequence matched the movement direction implied by the sentence

Zwaan, Stanfield, and Yaxley (2002)	
Independent variables	Study 1 and 2: • Sentences implying shape • Picture shape condition (match vs. mismatch with the shape implied by the sentence)
Dependent variables	Study 1 and 2: • Sentence comprehension
Data collection	• Reaction times • Naming task
Major result	Sentence processing was facilitated when the shape of picture stimulus matched the shape of an animal or object implied by the sentence

Yaxley and Zwaan (2007)	
Independent variables	• Sentences implying visibility • Occlusive medium (clean vs. fogged goggles)
Dependent variables	Sentence comprehension
Data collection	• Reaction times
Major result	Sentence processing was facilitated when depicted visual resolution matched the resolution implied by the sentence

******Contribution of Action Systems******

Bergen and Wheeler (2005)	
Independent variables	Study 1: • Implied sentence direction (toward vs. away) • Response direction (toward vs. away) • Type of sentence (describing literal motion vs. abstract motion Study 2: • Implied sentence shape (fist vs. palm) • Handshape response (fist vs. palm
Dependent variables	• Study 1 and 2: • Sentence comprehension
Data collection	• Reaction times

(continued)

Major result	Compatibility effect between actual hand movement and the movement implied by the sentence facilitated sentence comprehension. However, this effect was observed only for sentences describing literal motion rather than abstract. Details of the handshapes required to perform appropriate action were routinely involved in action simulation. Finally, action simulation was implicated in sentence processing even when language described action that did not involve the comprehender (third-person)
Borghi, Glenberg, and Kaschak (2004)	
Independent variables	Study 1: • Perspective (inside vs. outside) • Part location (inside vs. outside Study 2: • Perspective (inside vs. outside) • Part location (inside vs. outside • Distance (near vs. far) Study 3: • Condition (movement vs. no-movement) • Response direction ("yes-is-up" vs. "yes-is-down") • Part location (up vs. down)
Dependent variables	Study 1-3: • Retrieval of perceptual and motoric information during language comprehension
Data collection	• Correct response • Reaction times
Major result	Results from studies 1 and 2 demonstrate that participants are faster to verify inside parts of objects following the inside perspective sentence and faster to verify outside parts following the outside perspective sentence. Results from study 3 revealed that there were increased response times when literal response location matched implied part location, suggesting that action information is accessed to the same extent in processing of language as spatial information.

(continued)

Glenberg and Kaschak (2002)	
Independent variables	Study 1 and 2A: • Implied sentence direction (toward vs. away) • Response direction (toward vs. away) • Sentence type (imperative vs. concrete transfer vs. abstract transfer) Study 2B: • Implied sentence direction (toward vs. away) • Response format (left index finger over the "yes" button either near to or far from the body and right index finger over the "no" button either near to or far from the body) • Sentence type (imperative vs. concrete transfer vs. abstract transfer)
Dependent variables	Study 1 and 2A: • Sentence comprehension Study 2B: • Motor resonance
Data collection	• Proportion of correct judgments • Reaction times
Major result	Findings from Experiments 1 and 2A demonstrated a significant interaction effect between implied sentence direction and response direction (compatibility facilitated comprehension) and implied sentence direction and sentence type (sentences describing "away" movements were read faster than sentences describing "toward" movements in imperative and concrete transfer sentences; the inverse effect was observed for abstract transfer sentences). Experiment 2B showed no significant effect of the spatial location of response buttons on comprehension suggesting that the observed effects could only be accommodated by simulation theory

Tseng and Bergen (2005)	
Independent variables	• Type of sign (semantic vs. metaphorical) • Sign direction (backward vs. forward) • Response direction (backward vs. forward)
Dependent variables	• Retrieval of motoric information during language comprehension
Data collection	• Response times

(continued)

Results	Results revealed that making a decision about the form of a word led to activation of motor mechanisms. More precisely, Fluent signers of American Sign Language (ASL) were faster to indicate whether the two signs presented on the screen were the same or different when the direction of literal response matched the direction implied by literal and metaphorical motion signs. Authors interpreted this result as evidence for the fact that mere phonological processing of a lexical item with motion meaning engages the motor system
Wilson and Gibbs (2007)	
Independent variables	Study 1: • Type of literal movement (matching vs. mismatching vs. no-movement) • Implied metaphorical movement (matching vs. mismatching vs. no-movement) Study 2: • Type of imagined movement matching vs. mismatching vs. no-movement) • Implied metaphorical movement (matching vs. mismatching vs. no-movement)
Dependent variables	• Comprehension of metaphors
Data collection	• Reaction times
Major results	Results of both studies indicated that performing an action facilitated comprehension of metaphorical phrases related to those actions to the same extent as merely imagining performing an action
Zwaan and Taylor (2006)	
Independent variables	Study1: • Response rotation (clockwise vs. counterclockwise) • Visual rotation (clockwise vs. counterclockwise) • List (the mapping of a color change to response direction) Study 2: • Response rotation (clockwise vs. counterclockwise) • Implied sentence rotation direction (clockwise vs. counterclockwise)

(continued)

	Study 3: • Visual rotation (clockwise vs. counterclockwise) • Implied sentence rotation direction (clockwise vs. counterclockwise) Study 4: • Sentence region • Response rotation (clockwise vs. counterclockwise) • Implied sentence rotation direction (clockwise vs. counterclockwise) • Visual rotation (clockwise vs. counterclockwise) Study 5: • Illusionary rotation (half experiment clockwise and half experiment counterclockwise) • Sentence region • Response rotation (clockwise vs. counterclockwise) • Implied sentence rotation direction (clockwise vs. counterclockwise)
Dependent variables	Study 1: • Manual rotation Study 2 and 3: • Sentence processing Study 4 and 5: • Modulation of motor resonance in sentence processing
Data collection	Reaction times
Major result	Studies 1-3 provided evidence that language comprehension arises from simulating action experience. In particular, it was found that language processing was facilitated when manual rotation direction was consistent with the rotation direction described in the sentence. Studies 4 and 5 showed a limitation of compatibility effect between a sentence and a stimulus: motor resonance was significant for verb region of the sentence, but not for other parts of the sentence.

(continued)

******Contribution of Emotion Systems******

Havas, Glenberg, and Rinck (2007)	
Independent variables	Study 1 and 2: • Sentence valence (positive vs. negative) • Pen condition (pen-in-lips vs. pen-in-teeth) Study 3: • Type of prime word (neutral vs. associated) • Type of target (word vs. nonword) • Pen condition (pen-in-lips vs. pen-in-teeth)
Dependent variables	Study 1 and 2: • Sentence comprehension Study 3: • Lexical account
Major result	Study 1 and 2 demonstrated that judgment times for sentences describing pleasant events were faster when participants were smiling. Similarly, judgment times for sentences describing unpleasant events were faster when participants were frowning. Findings in Experiment 3 showed that the same pen manipulation procedure as in Studies 1 and 2 failed to influence the response speed in a lexical decision task suggesting that alternative amodal theories could not easily account for obtained results (e.g., Bower, 1981)

Havas, Glenberg, Gutowski, Lucarelli, and Davidson (2010)	
Independent variables	• Type of sentence (happy vs. sad vs. angry) • Session: preinjection, postinjection
Dependent variables	• Sentence comprehension • Reading times • Residual reading times • Comprehension-accuracy rates
Major result	Reading of angry and sad sentences was impaired after Botox injections. This finding is consistent with a simulation account suggesting that being prevented from frown makes it more difficult to simulate anger and sadness

Note: The information necessary to identify and retrieve each source can be found in the reference list

Annex B

Overview of Embodied Theories of Language Comprehension

Theory	Overview
Perceptual Symbol Theory (Barsalou, 1999a) ***1***	Language processing is embodied. First, during comprehension of the word, simulator for the word is extracted from original perceptual states. Second, simulator for the word becomes integrated with simulator for the concept it refers to (e.g., tree, trunk, and leaves). Third, the cognitive system utilizes the simulator of the concept that refers to the target word in order to derive meaning. *Major empirical studies where theory was tested:* • Pecher, Zeelenberg, and Barsalou (2004) • Simmons, Hamann, Harenski, Hu, and Barsalou (2008) • Solomon and Barsalou (2004) • Wu and Barsalou (2009)
Indexical Hypothesis (Glenberg & Robertson, 1999, 2000) ***1***	Language processing is embodied. First, words or phrases are indexed to corresponding perceptual symbols. Second, possible interactions with objects are simulated. These interactions are defined by relations among objects, bodily abilities (affordances), individual's goals for action, and experiences. Coherence is achieved by combining affordances guided by sentence syntax, experiences, and goals. *Major empirical studies where theory was tested:* • Glenberg, Gutierrez, Levin, Japuntich, and Kaschak (2004) • Glenberg and Robertson (2000) • Glenberg, Robertson, Jansen, and Johnson-Glenberg (1999) • Kaschak and Glenberg (2000) • Marley, Levin, and Glenberg (2007)

(continued)

Immersed Experienced Framework (Zwaan, 2004) ***1***	Language processing is embodied. There are three component processes of comprehension: activation, construal, and integration. During activation target words activate various experiences with referents (functional webs) in different visuospatial configurations. During construal functional webs are integrated in simulation of events implied by language. Integration refers to experientially-based transitions (e.g., visual, emotional) from one construal to another. *Major empirical studies where theory was tested:* • Stanfield and Zwaan (2001) • Zwaan, Madden, Yaxley, and Aveyard (2004) • Zwaan, Stanfield, and Yaxley (2002)
Action-based Language (Glenberg & Gallese, 2011) ***1***	Language processing is embodied and relies mainly on motor system. Comprehension is tantamount to predicting sensorimotor and affective effects of the performed action. Goal-directed mechanisms of action control (controller and predictor modules) which are involved in controlling of simple movements in motor cortex and more complex coordinated motor acts in pre-motor cortex are responsible for language comprehension. *Major empirical studies where theory was tested:* • Not found
Symbol Interdependency Hypothesis (Louwerse, 2007, 2008) ***2***	Language processing is both embodied and symbolic. Symbolic comprehension relies on interdependencies between the words and embodied comprehension relies on perceptual simulation that bridges the word with its referent in outside world. Symbolic system effectively does its job in most comprehension tasks as it represents shallow processing. However, when a comprehender engages in cognitive processing deeper than usual (e.g., visuospatial scenes), embodiment helps symbolic system to derive meaning. *Major empirical studies where theory was tested:* • Louwerse (2008) • Louwerse and Connell (2011) • Louwerse and Jeuniaux (2010)

(continued)

Language and Situated Simulation Theory (Barsalou, Santos, Simmons, & Wilson, 2008) ***2***	Language processing relies on symbolic systems, statistical representations, and simulation systems. The first system to be activated is symbolic. It represents shallow processing. When the resources of this system are not sufficient to derive meaning, simulation system which represents deep processing comes into play. Importantly, though the stress is being made on the fact that multiple systems represent knowledge, embodied account of meaning is considered to be the most relevant for cognition in this theory. *Major empirical studies where theory was tested:* • Santos, Chaigneau, Simmons, and Barsalou, (2011) • Simmons, Hamann, Harenski, Hu, and Barsalou (2008)

Note: Items marked as (*1*) refer to strong embodied theories and items marked with (*2*) refer to moderate embodied theories

Annex C

Complete Version of Tutorial Text in Portuguese used in Experiments on Emotion Simulation and Discourse Comprehension (Chapter 3)

Desta vez não é propriamente Verão, é Primavera avançada de fim de Maio. Nem sequer devia ir lá, devia ir apenas ao Faial apresentar o livro que te dediquei. Mas depois aconteceu aquela coisa estranha na Feira do Livro em Lisboa. Sentei-me à mesa de apresentação e na primeira fila estava uma rapariga a olhar para mim. Eu também olhei para ela e então ela levantou-se, aproximou-se de mim e disse, “Aproveito antes que comece a sua apresentação. Chamo-me Maria.”

Pomo-nos a caminhar juntos. Façamos um acordo, não vamos até lá abaixo, paramos a meio do caminho, sentamo-nos no chão sobre a lava negra que tem tantas formas estranhas e, às vezes, encontram-se algumas que se adaptam bem a um corpo humano, que quase parecem ter sido modeladas precisamente num corpo.

Todos podem escolher a sua. Aqui o vento não é muito forte e nem sequer o ruído do mar. Às vezes, o vento leva-o mesmo embora e então vê-se o mar mas não se ouve. O vente com o sol parece fogo.

Depois, à noite, refresca um pouco, mas levando tempo, e lentamente, porque a terra afogueada durante tantas horas emite o seu calor ainda por muito tempo. E assim, ao caminhar sobre ela, podemos senti-ló a subir pelas pernas, chegar até aos joelhos, exatamente como uma brisa de fogo. O sol na estrada 21 queima só de caminhar por alguns instantes.

Ao longe vêem-se as primeiras luzes de Madalena. Somente algumas luzes, visto que é a vila principal, apenas o suficiente para poder dizer que há iluminação. O bar da praça ainda está aberto, bem como um restaurante onde já não deve estar ninguém. Nesta estação tem início o pouco turismo da ilha que durará alguns meses, felizmente ainda pouca coisa.

Pois, como se eu também não fosse uma turista. Mas estou a ir-me embora, o que me importa a mim quem chega? A história do costume, querer saber de tudo incontaminando, mesmo à distância. Pergunto-me sempre estas coisas onde quer que vá, se os habitantes locais também fazem o que os turistas geralmente gostam de fazer, porque eu acho mesmo que não, que no mesmo lugar existem duas vidas diferentes e paralelas, e o que o turista geralmente faz é algo desconhecido para quem vive no mesmo lugar. E onde quer que vá tento nunca fazer o que os turistas fazem porque de outro modo parecer-me-ia nunca aí ter estado.

(continued)

Annex C (continued)

Complete Version of Tutorial Text in Portuguese used in Experiments on Emotion Simulation and Discourse Comprehension (Chapter 3)

Está a fazer-se muito tarde. Este dia está a começar a tornar-se pesado e começo a sentir o cansaço. Por que? Sabe-se lá o que me deu para vir aqui. As recordações, as recordações são verdadeiramente estranhas, muito estranhas. Tem-se sempre a sensação de recordar de uma maneira, mas se pudéssemos realmente voltar atrás, reviver aquela recordação, então descobri-la-íamos sem dúvida completamente diferente de como a recordámos durante tanto tempo.

Os acrescentos do presente, os que metes lá dentro mesmo quando não recordas a recordação. São eles que a mudam, e assim acabas por te recordar de algo diferente, alterado por tua vida. Recordações, recordações, recordações...

Annex D

Complete Version of Target Text in Portuguese used in Experiments on Emotion Simulation and Discourse Comprehension (Chapter 3)

Um finlandês de oitenta e um anos casou-se com uma mulher finlandesa de cinquenta e quatro que conheceu na Internet, demonstrando que o amor vence todos os obstáculos. Jan-Erik Enestam, mais conhecido pelo seu livro «O Amor chega com a idade», afirma que «a Internet não pertence apenas aos jovens. Não existem quaisquer regras que impeçam as pessoas idosas de procurar o amor online,» afirma o feliz advogado reformado que usa a Internet há já cerca de dez anos.

Os pais da noiva, de setenta e seis e setenta e dois anos, não ficaram muito contentes com a escolha da filha, porque o homem tem problemas de visão e, claro, por causa da sua idade. No entanto, a felicidade da filha e o sorriso constante na face desta, fizeram com que aceitassem Jan-Erik na família.

Quando lhe perguntaram porque motivo escolhera Jan-Erik para seu futuro marido, Mikko Koskinen disse: «Bem, a sua voz pareceu-me muito jovem e descobri que era um homem extremamente afectuoso».

«Após oito meses de casamento, o meu marido de oitenta e um anos ainda tem gestos para comigo que os meus quatro maridos anteriores nunca tiveram. Por exemplo, traz-me sempre café à cama, oferece-me as minhas flores favoritas e por vezes chega até a preparar jantares românticos à luz da vela», disse Mikko, com um enorme sorriso estampado no rosto.

Um dia, o casal decidiu trocar as ruas cheias de neve da capital finlandesa por umas férias no Egipto, de forma a assinalar o primeiro aniversário do seu casamento. Como a mulher era vendedora imobiliária e tinha um horário muito sobrecarregado, decidiram que o marido voaria primeiro e que a mulher se juntaria a ele no dia seguinte. E assim sucedeu.

Quando o avião do homem aterrou no Cairo a primeira coisa que ele viu ao desembarcar foram enormes vagas e nuvens de areia vermelha subindo e rolando em frente como ondas gigantes. A temperatura dava-lhe a impressão de estar num grelhador, particularmente para um homem que passara toda a sua vida na gelada Finlândia. Todavia, apesar do clima, as impressões do homem sobre o Egipto foram todas positivas. No autocarro que o levou ao hotel, Jan-Eric teve a oportunidade de apreciar os locais mais belos que alguma vez vira na sua vida: as sombras das Grandes Pirâmides, o Vale dos Reis e o templo de Abu Simbel.

Ao chegar ao hotel, decidiu enviar à mulher um *email* sucinto. Infelizmente, ao escrever o endereço dela, falhou um letra e, ao invés de seguir para a mulher, o recado foi parar à caixa de correio de uma idosa, esposa de um padre, cujo marido de sessenta e sete anos falecera precisamente no dia anterior. Quando a viúva enlutada decidiu verificar o seu *email*, deu uma vista de olhos ao monitor, soltou um grito estridente e caiu ao chão sem sentidos.

(continued)

Annex D (continued)

Complete Version of Target Text in Portuguese used in Experiments on Emotion Simulation and Discourse Comprehension (Chapter 3)

Ao ouvirem o barulho, a família correu para o quarto e viu o seguinte recado no ecrã:
Minha Querida Esposa,
Acabo de fazer o check-in. Está tudo preparado para a tua chegada amanhã.
Tem em conta que aqui faz um calor terrível.

Annex E

Questionnaire Items Used in Experiment 3 to assess "Online" Discourse Comprehension

- *Perceived reading ease*

Indique o grau em que concorda com as seguintes afirmações registando a sua resposta numa escala crescente de 1 (*Discordo muito*) a 7 (*Concordo muito*).

	Discordo muito						**Concordo muito**
Eu não tive qualquer dificuldade em compreender os detalhes do texto	1	2	3	4	5	6	7
Achei o processo de leitura do texto fácil	1	2	3	4	5	6	7

- *Vividness of mental imagery*

Quando eu estava a ler o texto, a imagem da apresentação do discurso na minha mente era:

Vívida	1	2	3	4	5	6	7	Vaga
Clara	1	2	3	4	5	6	7	Nada clara
Indistinta	1	2	3	4	5	6	7	Distinta
Nítida	1	2	3	4	5	6	7	Embaciada
Intensa	1	2	3	4	5	6	7	Fraca
Natural	1	2	3	4	5	6	7	Inerte
Desfocada	1	2	3	4	5	6	7	Clara

- *Spatial presence*

Quando eu estava a ler o texto, tinha a sensação que:

	Discordo muito						**Concordo muito**
Eu estava no centro da acção descrito no texto e não era um mero observador	1	2	3	4	5	6	7
Eu fazia parte do ambiente descrito no texto	1	2	3	4	5	6	7
Eu estava realmente lá no meio da apresentação	1	2	3	4	5	6	7
Os objetos na apresentação estavam em meu torno	1	2	3	4	5	6	7
A minha verdadeira localização deslocou-se no meio da apresentação	1	2	3	4	5	6	7
Eu estava fisicamente presente no meio da apresentação	1	2	3	4	5	6	7
Eu realmente fiz parte do ambiente da apresentação	1	2	3	4	5	6	7

Annex F

Questionnaire Items Used in Experiment 3 to assess “Offline” Discourse Comprehension

- *The Questions Used to Test Explicit Comprehension of Discourse in Experiment 1*

1. Qual é a diferença de idade entre o homem e a mulher?
2. Por quantos anos o homem estava a usar a Internet?
3. Qual é o problema de saúde que o homem tem?
4. De que país o homem e a mulher se originam?
5. Qual é a profissão da mulher?
6. Para quem o homem enviou o e-mail?
7. Qual era a profissão do homem?
8. Como é que o casal se conheceu?
9. Por que razão o casal decidiu ir para o Cairo?
10. Que época do ano era na cidade onde o casal vivia quando eles decidiram ir para o Cairo?

- *The Statements Used to Assess Implicit Comprehension of Discourse in Experiment 1*

	Discordo muito						**Concordo muito**
1. O marido está feliz no casamento	1	2	3	4	5	6	7
2. A mulher está feliz no casamento	1	2	3	4	5	6	7
3. O marido está actualmente desempregado	1	2	3	4	5	6	7
4. O casal vive na cidade com a população superior a 50.000 pessoas	1	2	3	4	5	6	7
5. O relacionamento do casal é romântico	1	2	3	4	5	6	7
6. O tempo no Cairo estava ventoso, quando o homem chegou	1	2	3	4	5	6	7
7. A temperatura no Cairo eatava acima de 30 º C	1	2	3	4	5	6	7
8. Enquanto ia de autocarro para o hotel, o homem podia ver muitos sítios históricos	1	2	3	4	5	6	7
9. O homem digitou incorretamente o endereço de e-mail da sua esposa por causa da baixa visão	1	2	3	4	5	6	7
10. A esposa do homem era casado antes	1	2	3	4	5	6	7

Annex F (continued)

11. O homem estava à procura do amor online há mais de um ano	1	2	3	4	5	6	7
12. Foi difícil para os pais da noiva darem o seu consentimento para o casamento	1	2	3	4	5	6	7
13. O marido é um tipo de homem bem humoroso	1	2	3	4	5	6	7
14. O marido gosta de história	1	2	3	4	5	6	7
15. O casal está a desfrutar da sua felicidade	1	2	3	4	5	6	7

Annex G

List of Control Variables Used in Experiments 1 and 2

The Items Used to Assess the Perceived Attention Grabbing in Experiment 1

Indique o grau em que concorda com as seguintes afirmações registando a sua resposta numa escala crescente de 1 (*Discordo muito*) a 7 (*Concordo muito*).

	Discordo muito						**Concordo muito**
1. O texto está a prender a atenção	1	2	3	4	5	6	7
2. O texto é cativante	1	2	3	4	5	6	7
3. O texto é intrigante	1	2	3	4	5	6	7

The Items Used to Assess Reading Satisfaction in Experiment 1

Indique o grau em que concorda com as seguintes afirmações registando a sua resposta numa escala crescente de 1 (*Discordo muito*) a 7 (*Concordo muito*).

	Discordo muito						**Concord muito**
1. O meu nível de satisfação com o texto é alto	1	2	3	4	5	6	7
2. Achei o processo de leitura do texto agradável	1	2	3	4	5	6	7
3. Ao terminar a leitura do texto, senti-me como se não conseguisse parar de sorrir	1	2	3	4	5	6	7
4. No futuro, eu gostaria de ler, ansiosamente, uma outra história deste tipo	1	2	3	4	5	6	7

The Items Used to Assess Social Evaluation of the Protagonist in Experiment 1

Quando eu estava a ler o texto, eu imaginava o homem a ser:

Entusiasta	1	2	3	4	5	6	7	Nada entusiasta
Brincalhão	1	2	3	4	5	6	7	Nada brincalhão
Jovem	1	2	3	4	5	6	7	Idoso
Alegre	1	2	3	4	5	6	7	Triste
Lisonjeiro	1	2	3	4	5	6	7	Nada lisonjeiro
Animado	1	2	3	4	5	6	7	Deprimido
Apaixonado	1	2	3	4	5	6	7	Desapaixonado
Afortunado	1	2	3	4	5	6	7	Infeliz
Dinâmico	1	2	3	4	5	6	7	Passivo
Otimista	1	2	3	4	5	6	7	Pessimista
Animado	1	2	3	4	5	6	7	Apático
Bem-aventurado	1	2	3	4	5	6	7	Infeliz

Annex H

Complete Version of Tutorial Text in Portuguese used in Experiment on Simulation of Spatial Dimension and Discourse Comprehension (Chapter 4)

Desta vez não é propriamente Verão, é Primavera avançada de fim de Maio. Nem sequer devia ir lá, devia ir apenas ao Faial apresentar o livro que te dediquei. Mas depois aconteceu aquela coisa estranha na Feira do Livro. Sentei-me à mesa de apresentação e, na primeira fila, estava uma rapariga a olhar para mim. Eu também olhei para ela e então ela levantou-se, aproximou-se de mim e disse, “Aproveito antes que comece a apresentação. Chamo-me Silvia.”

Pomo-nos a caminhar juntos. Façamos um acordo, não vamos até lá abaixo, paramos a meio do caminho, sentamo-nos no chão sobre a lava negra que tem tantas formas estranhas e, às vezes, encontram-se algumas que se adaptam bem a um corpo humano, que quase parecem ter sido modeladas precisamente num corpo. Todos podem escolher a sua. Aqui o vento não é demasiado forte, e nem sequer o ruído do mar. Às vezes, o vento leva-o mesmo embora, e então vê-se o mar mas não se ouve. O vente com o sol parece fogo...

Depois, à noite, refresca um pouco, mas levando tempo, e lentamente, porque a terra afogueada durante tantas horas emite o seu calor ainda por muito tempo. E assim, ao caminhar sobre ela, podemos senti-ló a subir pelas pernas, chegar até aos joelhos, exactamente como uma brisa de fogo. O sol na estrada de Arcos, é mais sol do que em qualquer outro lugar, quiema só de caminhar por alguns instantes. E tudo treme, até um corpo. Faz um calor sem tréguas.

Ao longe vêem-se as primeiras luzes de Manna. Somente algumas luzes, visto que é a vila principal, apenas o suficiente para poder dizer que há iluminação. O bar da praça ainda está aberto. Nesta estação tem início o pouco turismo da ilha que durará alguns meses, felizmente ainda pouca coisa.

Pois, como se eu também não fosse uma turista. Mas estou a ir-me embora, o que me importa a mim quem chega? A história do costume, querer saber de tudo incontaminado, mesmo à distância. Pergunto-me sempre estas coisas onde quer que vá, se os habitantes locais também fazem o que os turistas geralmente gostam de fazer, porque eu acho mesmo que não, que no mesmo lugar existem duas vidas diferentes e paralelas: de turista e de habitante.

Este dia está a começar a tornar-se pesado e começo a sentir o cansaço. Sabe-se lá o que me deu para vir aqui. As recordações... Não é nada melhor do que a recordação de um amor falhado, podem-se fazer quantos apêndices quisermos, é como se estivesse tudo ainda por fazer. Sabe-se lá o que seria de um amor falhado se subitamente se tornasse um amor verdadeiro...

Os acrescentos do presente, os que metes lá dentro mesmo quando não recordas a recordação. São eles que a mudam, e assim acabas por te recordar de algo diferente, alterado por tua vida. Se realmente é assim, é como se não tivéssemos passado. O passado que se transforma, ganha um novo aspecto.

Annex I

Complete Version of Target Text in Portuguese used in Experiment on Simulation of Spatial Dimension and Discourse Comprehension (Chapter 4)

Ele olha para o seu relógio de pulso, são 21H00.

Deixa-a para trás com a dor que foi forçado a aceitar. A vertigem da liberdade acelera-lhe o ritmo cardíaco, alimenta os seus sonhos mais ousados de ter uma vida normal. Os trinta e quatro anos de toda a sua existência, a existência que o trouxe até este momento, não voltarão mais a ser recordados. Não pode fazer o tempo andar para trás no seu relógio de pulso de maneira a trazer a mulher de volta.

O coração, já estilhaçado em pedaços, faz o sangue fluir com uma velocidade incrível por todo o seu corpo, à medida que observa pela janela da sua viatura outros carros passarem pelo seu. Na escuridão do momento, os seus olhos, de um azul profundo, estão repletos de mágoa e de lágrimas. Todo o seu corpo parece anestesiado, como se fosse uma bateria descarregada. Mas ele sabe que tem de esquecer. Se a condução veloz e durante muito tempo fizer com que se apague o passado, então ele será bem sucedido.

À medida que vai guiando, sonha com ela. Sonha com a altura em que se casaram e trocaram alianças; sonha com o tempo em que a ensinou a montar a cavalo; sonha com o tempo em que, ao abrir a porta da casa após um árduo dia de trabalho, ela lá estava, à espera do seu homem. Finalmente, sonha com o cheiro da pele dela, o cheiro do seu perfume, o cheiro da sua presença… Agora, tudo isso desapareceu. O mundo parece cinzento, frio e destituído de sentido.

O horrível rugido do motor do carro fá-lo voar a uma velocidade incrível, ultrapassando viaturas umas atrás das outras. Mas depressa percebe que falha no desejo de escapar ao mundo. Pára o carro, vira-se para trás no assento com o intuito de verificar se escapou dela, do passado, de si mesmo.

Olha para fora da janela, tremendo perante a noite que lhe obstrui a visão. «Onde estou?» - questiona-se. Mas não há ninguém para responder; não há ninguém que o possa ajudar a ultrapassar a dor que lhe chega do fundo do seu coração partido. Reunindo todas as suas forças, respira fundo e sai do carro. Já se sente o ar gelado e ele consegue pressentir o frio da noite a aproximar-se. O céu enche-se de nuvens; o vento sopra na sua face.

Retira um cigarro do bolso da camisa e fuma. Após a fadiga da fome, após as tremuras violentas, o após o excesso de humidade, o cheiro do cigarro é a única consolação que lhe resta, perdido que está no meio de nenhures. Subitamente, começa a chover, numa grande bátega de água, e ele compreende que neste mundo enorme não passa de um ser completamente miserável.

Deseja que tudo não passe de um sonho. Mas não é um sonho. Apesar da adrenalina que pulsa pelo seu coração, a fadiga, o frio intenso e a falta de comida, ainda sente a presença dela. Ela continua consigo na aliança de casamento na sua mão, declarando simbolicamente o seu amor eterno por ele…

Annex J

Questionnaire Items Used in Experiment 3 to Assess “Online” and “Offline” Discourse Comprehension

- *The Items Used to Measure Vividness of Mental Imagery Regarding Static Locations in the Left Spatial Dimension in Experiment 3*

Quando eu estava a ler o texto, eu podia:

	Discordo muito						**Concordo muito**
Imaginar a batida de coração do homem	1	2	3	4	5	6	7
Imaginar a aliança na mão dele	1	2	3	4	5	6	7

- *The Items Used to Measure Vividness of Mental Imagery Regarding Static Locations in the Left Spatial Dimension in Experiment 3*

Quando eu estava a ler o texto, eu podia:

	Discordo muito						**Concordo muito**
Imaginar o homem a conduzir rápido	1	2	3	4	5	6	7
Imaginar o homem a voltar no seu banco de motorista	1	2	3	4	5	6	7
Imaginar o homem a sair do carro	1	2	3	4	5	6	7

- *The Items Used to Measure Vividness of Mental Imagery Regarding Movements that Involve Two Persons in the Left Spatial Dimension in Experiment 3*

Quando eu estava a ler o texto, eu podia:

	Discordo muito						**Concordo muito**
Imaginar o casal a trocar alianças na cerimónia de casamento	1	2	3	4	5	6	7
Imaginar o homem a ensinar a sua esposa como se monta o cavalo	1	2	3	4	5	6	7

- *The Statements Used in the Sequencing Task in Experiment 3 (“offline” comprehension”)*

Coloque os eventos do texto na ordem correta

1. O homem observa pela janela da sua viatura outros carros passarem pelo seu
2. O homem sonha com a sua mulher
3. O homem sai do carro
4. O homem retira um cigarro do bolso da camisa e fuma

Annex K

Complete Version of Tutorial Text in Portuguese used in Experiments on Action Simulation and Discourse Comprehension (Chapter 5)

Desde o primeiro ano da escola que todos me tratam por Fomenicas. Sou magro e a minha cara parece de cera, mas nunca passei um dia sem comer. Sim, tenho cara de fome e os ossos cobrem-se quase só de pele; nisso saio ao meu tio Nuno, que num dia, ao almoço, foi capaz, de comer dois quilos de bacalhau e quatro de batatas com dois litros de vinho, e um pão de quilo. Todo o mundo julgou que ele iria rebentar com uma pançada daquelas. Bom, o que quero explicar é que a minha magreza não tem nada a ver com a fome.

Como todos os dias ao almoço dois pratos de sopa com pão e ao jantar mais dois. Para a escola, a minha mãe arranjava-me sempre um papo-seco com linguiça, não julgassem os outros que a gente passava mal em minha casa. Pois, mesmo assim, puseram-me a alcunha de Fomenicas. Depois dessa arranjaram-me outras, como Guita e Magriço, mas cada uma não resistiu à força da primeira.

Não me lembro quem ma pôs, nem agora isso interesa para o caso. Tenho a certeza que devo à alcunha o tornar-me alvo das brincadeiras da escola. A malta fazia luxo em meter-se comigo, dar-me chulipas e inventar castigos para mim se eu refilava ou mostrava má cara. Acabei por me habituar e fingir que também entrava na paródia. Mas só eu sei o que sentia cá por dentro. Hoje ainda ninguém me fez mal, apesar de estarem dez rapazes no corredor da secretaria. Vejo-os nervosos, conversando uns com os outros à procura de qualquer pretexto para gracejarem. Mas hoje nem eu lhes sirvo.

Tenho a certeza de que vivo hoje o meu último dia de escola. Preparei-me para o exame final com todas as minhas forças, na certeza de que uma vida nova vai começar para mim; quanto melhor for a nota do diploma, mais facilmente poderei alcançar o meu sonho destes anos. Prestei as melhores provas de todo o curso. Os livros pareciam abertos à minnha frente e havia vozes que me sopravam toda a matéria das disciplinas. Tirei a minha grande desforra; estou certo de que nenhum outro me passará à frente.

É possível que ainda encontre algum deles na minha carreira de empregado de esritório, e esse há-de arrepender-se de todo o mal que me fez ou aplaudiu. Sinto que vou vencer todas as batalhas da minha profissão. À minha volta as coisas já começaram a modificar-se; não me lembro agora da roupa velha de que tanto me envergonhava. Hoje estreei o fato que o meu pai comprou no mercado.

(continued)

Annex K (continued)

Complete Version of Tutorial Text in Portuguese used in Experiments on Action Simulation and Discourse Comprehension (Chapter 5)

As noites que passei já não voltam. Recordo-me da última em que preparava o exame de escrituração: o meu pai, na casa de entrada, batia a sola para um conserto que devia entregar pela manhã. Não podia suplicar-lhe que adiasse o trabalho, pois não havia dinheiro em casa e ele ganhava para o nosso almoço. Arregalei os olhos, para com eles absolver tudo o que devia ainda estudar.

Encafuara-me no quarto com uma vela a iluminar-me, procurando alhear-me de todos os ruídos, de olhos bem atentos às páginas do livro e de mãos encostadas aos ouvidos para que nada pudesse distrair-me. Mas o bater do martelo andava decorado pelo meu sangue...

Annex L

Complete Version of Target Text in Portuguese used in Experiments on Action Simulation and Discourse Comprehension (Chapter 5)

Ao protegermos a vida da nação e ao resguardarmos as liberdades dos cidadãos, perseguimos a nossa própria felicidade. O sucesso nesse objectivo corresponde ao nosso sucesso enquanto nação. A vossa imaginação, a vossa iniciativa e a vossa criatividade ajudar-nos-ão a construir uma sociedade onde o progresso está ao serviço das nossas necessidades. E isto porque, no vosso tempo, temos a oportunidade de avançar não só em direcção a uma sociedade próspera e ponderosa, mas também em direcção à Grande Sociedade.

Temos uma falsa sensação de independência; no caminho para um amanhã melhor os nossos navios podem colidir e afundar-se. No entanto, se nos comprometermos com novas prioridades, com novas estratégias e formas novas de pensamento que assegurem que a esperança se mantenha viva, quebraremos a muralha da hesitação e em segurança navegaremos o nosso barco para um futuro melhor.

Assim, quero hoje falar-vos sobre os lugares onde começamos a construir esta Grande Sociedade; as nossas cidades, as nossas salas de aula. Muitos de nós viverão para ver chegar o dia, talvez daqui a cinquenta anos, em que a nossa população e área das cidades dobrará; o dia em que todos juntos daremos um passo de gigante para construirmos casas, auto-estradas e infra-estruturas equivalentes em número a todas as que foram erigidas desde a criação do nosso país. Portanto, nos próximos quarenta anos, construiremos a ponte que pavimentará o caminho para esta Grande Sociedade.

A nossa sociedade nunca será grandiosa enquanto as nossas cidades não forem grandiosas. Nas asas do tempo, aproximamo-nos rapidamente de uma era em que a imaginação e a inovação se tornam as maiores prioridades. Usem a vossa imaginação e a vossa esperança como armas do nosso progresso para a Grande Sociedade. Do mesmo modo que os atletas numa corrida não param enquanto não chegam à meta, também vós assim devem agir. Avancem, abram os braços a qualquer ideia que nos possa conduzir a um futuro melhor.

A nossa sociedade nunca poderá ser grandiosa enquanto mais de um quarto da mesma não tiver completado o ensino secundário. A cada ano, mais de 10.000 alunos finalistas do ensino secundário, com habilitações demonstradas, não entram na universidade porque não têm dinheiro para isso. E, se não conseguimos educar a juventude de hoje, não poderemos perseguir o futuro com confiança.

(continued)

Annex L (continued)

Complete Version of Target Text in Portuguese used in Experiments on Action Simulation and Discourse Comprehension (Chapter 5)

É obvio que ainda temos muitos problemas nas nossas escolas, mas em simultâneo passámos do caminho da discórdia para o do acordo. Ao avançarmos neste caminho, temos de ir além dos currículos, que estão desactualizados, e caminhar lado a lado com as correntes do futuro, de forma a encontrar novas maneiras de estimular o gosto pela aprendizagem e a capacidade da criação.

Estão são os dois aspectos centrais da Grande Sociedade. Devemos reunir o melhor do pensamento e o mais amplo do conhecimento de todo o mundo de forma a caminharmos para um futuro melhor juntos e a abrirmos um novo capítulo na história da nossa grande nação.

Annex M

List of Stimuli Used in Judgment and Recognition Tasks in Experiments 4 and 5

- *List of Sentences Used in a Judgment Task for Experiments 4 and 5*

TAREFA: O objectivo desta tarefa é identificar se as frases apresentadas são verdadeiras ou falsas de acordo com o texto que acabou de ler. Pretende-se que seja um exercício rápido. Irá surgir no ecrã a palavra 'PREPARE-SE' e, após 3 segundos, aparecerá uma frase. Rapidamente, carregue na Tecla 'A' se verificar que a frase é falsa de acordo com o texto e na Tecla 'L' se verificar que a frase é verdadeira de acordo com o texto. Após a sua selecção, aparecerá novamente a palavra 'PREPARE-SE', e após 3 segundos, uma nova frase para análise.

Measure	Sentence
Explicit comprehension	Os lugares para começar a construer a Grande Sociedade são as escolas e as salas de aula Muitos alunos não entram na universidade devido a problemas financeiros
Implicit comprehension	A modernização é um aspect importante de Grande Sociedade A juventude é a esperança do país
Incorrect control sentences	Em 50 anos quer a população quer a area das cidades passarão a metade Dinheiro é um aspect essencial de Grande Sociedade

- *List of Words Used in a Recognition Task*

TAREFA: O objectivo desta tarefa é identificar as palavras que encontrou no texto 'GRANDE SOCIEDADE' durante a leitura efectuada. Pretende-se que seja um exercício rápido. Irá surgir no ecrã a palavra 'PREPARE-SE' e, após 3 segundos, aparecerá uma segunda palavra. Rapidamente, carregue na Tecla 'A' se verificar que esta palavra não pertence ao texto e na Tecla 'L' se associar a palavra ao mesmo. Após a sua selecção, aparecerá novamente a palavra 'PREPARE-SE', e após 3 segundos, uma nova palavra para análise.

Type	Words
Words from the text implying movement	Perseguir (x2), avancar, aproximar-se, caminhar, conduzir
Words from the text not implying movement	Ajudar, sociedade, começar, grande, assegurar, poder
Words of movement not from text	Corer, ir, marchar, atravessar, deslocar