Discourse comprehension and simulation of positive emotions

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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 while their facial postures were manipulated to be either congruent (matching condition) or incongruent (mismatching condition) with emotional valence of the text. In addition, a control condition was included in which participants read the text naturally (without a manipulation of facial posture). The influence of emotion simulation on discourse understanding was assessed by online (self-paced reading times) and offline (verbatim and inference questions) measures of comprehension. The major result was that participants read faster the target text describing positive emotional events while their bodily systems were prepared for processing of positive emotions (matching condition) rather than unprepared (control condition) or prevented from positive emotional processing (mismatching condition). Simulation of positive emotions did not have a significant impact on offline explicit and implicit discourse comprehension. This pattern of results suggests that emotion simulation has an impact on online comprehension, but may not have any effect on offline discourse processing.

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, 2008; 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, Robertson, Glenberg, Kaschak, & Rinck, 2004; Hauk, Johnsrude, & Pulvermüller, 2004; Santana & de Vega, in press; 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, Glenberg, and Rinck (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, Glenberg, Gutowski, Lucarelli, and Davidson (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, Millis, & Zwaan, 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, Singer, & Trabasso, 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, Santos, Simmons, and Wilson (2008) simulation system represents deeper conceptual processing compared to 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, Solomon, & Wu, 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, Goldberg, & Zhu, 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, van Dantzig, Zwaan, and Zeelenberg (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).

Overview of the Experiment and Hypotheses

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, our 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.

Firstly, participants read a neutral non-emotional text. Secondly, participants were randomly assigned to one of the three conditions and

asked to read a target text identical in size to the previous non-emotional text. More precisely, participants in the matching condition read the target text while holding the pen sideways between the teeth to force a partial smile (Oberman, Winkielman, & Ramachandran, 2007). Participants in the mismatching condition read the target text while having a pen straight between the lips, without touching the pen with their teeth, to prevent smile (Oberman et al., 2007; Strack, Martin, & Stepper, 1988). Participants in the control (neutral) condition read the target text in a normal condition without a pen. Participants read tutorial and target texts while their paragraph reading times were measured. Thirdly, participants answered a set of filler questions, designed to free up the working memory. Finally, participants replied to verbatim and inference questions checking offline explicit and implicit comprehension of the target text. With regard to online processing, we expected that comprehension would be facilitated when 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 while having a pen between their lips (mismatching condition), or in a normal condition without a pen (control condition). With regard to offline processing, we 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 mismatching and control conditions.

METHOD

Participants. A total of 60 Portuguese citizens ranging in age from 18 to 58 (M_{age} = 26.72, SD_{age} = 8.50) participated in the experiment: 26 participants were male (M_{age} = 29.42; SD_{age} = 10.93), 32 were female (M_{age} = 24.63; SD_{age} = 5.36), and two participants did not indicate gender. The sample is composed of students (60%) and workers (31.7 %; 8.3% of participants did not indicate their profession). The matching group included 11 female and 9 male participants between the ages of 18 and 58 years (M_{age} = 27.75; SD_{age} = 10.47). The mismatching group included 9 female and 10 female participants (1 gender missing data) between the ages of 19 and 52 years (M_{age} = 27.15; SD_{age} = 9.22). The control group included 12 female and 7 male participants (1 gender missing data) between the ages of 18 and 35 years (M_{age} = 25.25; SD_{age} = 5.13). Everyone who took part in the study received a copybook in exchange for participation.

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

Tutorial and Target Texts. The materials consisted of two texts (tutorial and target) and a questionnaire. The tutorial text was neutral as it contained a lot of factual and descriptive information about protagonist's life on a Faial Portuguese Island of the Azores (see Annex A). The target text described emotionally positive events (see Annex B). 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.

A pre-test study was first conducted to assess the emotional valence of both texts. Sixteen university students were asked to indicate the degree of neutrality and pleasantness of both texts on a 7-point scale ranging from 1 *(completely disagree)* to 7 *(completely agree)*. On average, participants found the tutorial text more neutral ($M = 3.44$; $SD = 1.37$) than the target text ($M = 2.31$; $SD = 0.87$), $t (15) = 3.00$, $p = .009$, $r = .61$. Also, participants found reading of the target text more pleasant ($M = 5.94$; $SD = 0.93$) than reading of the tutorial text ($M = 4.06$; $SD = 1.48$), $t (15) = -4.86$, $p = < .001$, $r = .78$. Thus, we concluded that the target text was indeed seen as conveying significantly more emotional content than the tutorial text.

Online and offline discourse comprehension measures. Online discourse comprehension was assessed by collecting reading times for whole paragraphs as readers normally read the text. Offline comprehension of discourse was assessed by questions used in standardized reading assessments (see Alderson, 2000; Hughes, 2003, for discussion). More precisely, to measure explicit comprehension participants were asked to answer to 10 verbatim questions about information explicitly given in the target text (e.g., "How did the man and woman meet?", "What is woman's profession?"). The performance indicator was the mean number of correct answers. 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 (no reverse-coded items were used) based on implicit guessing. 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. Implicit comprehension scale showed good reliability (Cronbach's alfa = .73). 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. Importantly, to free up the working memory of participants and ensure that text reading and offline comprehension task were separated in time, all participants were first instructed to respond to 43 filler questions that did not assess offline processing of discourse.

Procedure. Participants were contacted by experimenters at university campus and asked to participate in the study 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 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 while having a pen between their teeth. Participants in the mismatching condition read the text while having a pen between their lips. Participants in the control condition read the text naturally without any manipulation with a pen. The 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 instructed to fill in the text-related paper-based questionnaire. Finally, in post-experimental interview

participants were asked whether they guessed the purpose of pen manipulation in order 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, 1994) suggests that participants who are aware of emotion manipulation tend to regulate their responses more effectively, and thus their responses can bias the results.

RESULTS

Online comprehension measures

Target text reading time. An 8 (Paragraphs 1 to 8) within factor x 3 (condition: matching *vs*. mismatching *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 speeds. The results showed that tutorial reading time (reported in milliseconds) was significantly related to the participant's target text reading time, $F(1, 56) = 429.19$, $p < .001$, partial $\eta^2 = .86$. There was also a significant effect of pen condition on target text reading time after controlling for the effect of the tutorial reading time, $F(2, 56) = 9.93$, $p < .001$, partial $\eta^2 = .26$. Planned contrasts revealed that participants in the matching condition ($M = 16046.57$; $SE = 396.81$) read the target text significantly faster than participants in the control condition ($M = 17952.25$; $SE = 395.03$), $t(56) = -3.43$, $p = .001$, $r = .42$ and participants in the mismatching condition ($M = 18448.02$; $SE = 405.81$), $t(56) = -4.15$, $p < .001$, $r = .48$. At the same time, participants in the mismatching condition did not significantly differ in their reading speed of the target text from participants in the control condition, $t(56) = 0.86$, $p > .10$, $r = .11$.

There was also a significant effect of pen condition on the speed with which participants read paragraphs of text, $F(16, 100) = 2.34$, $p = .005$. Follow-up analyses comparing pairs of conditions (Table 1 and Figure 1) demonstrated that reading times in the matching condition were significantly faster than in the control condition when participants read paragraphs one ($p = .030$), three ($p = .021$), five ($p = .003$), six ($p = .045$), and seven ($p = .022$), and marginally faster when participants read paragraph two ($p = .081$). Also, reading times in the matching condition were significantly faster than in the mismatching condition when participants read paragraphs one ($p = .013$), two ($p = .002$), three ($p < .001$),

four ($p = .028$), five ($p = .003$), and six ($p < .001$). Finally, the reading times in the mismatching condition were marginally slower than in the control condition only for paragraph six ($p = .069$). No differences in reading speed were found between mismatching and control conditions for other paragraphs.
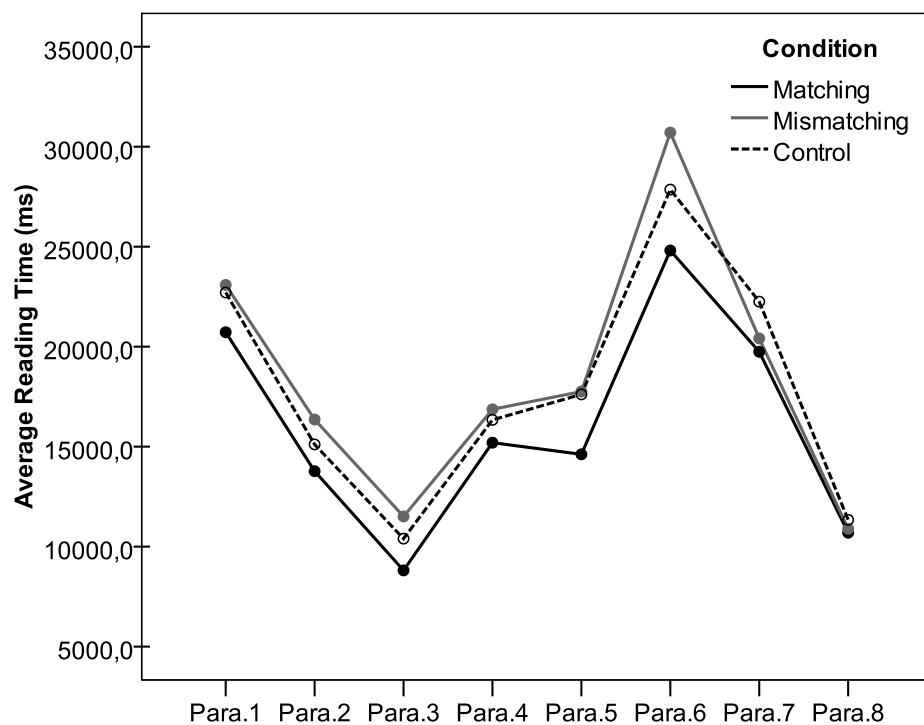

Figure 1. Mean reading times in milliseconds (estimated marginal means) for eight paragraphs of the target text according to condition (Matching vs. Mismatching vs. Control).

Offline comprehension

Explicit comprehension. A 3 (condition: matching *vs*. mismatching *vs*. control) between-participants ANOVA was conducted on the number of correct answers to open questions. The results revealed that there was no effect of pen condition on explicit comprehension of discourse, $F\ (2, 50) = 1.42, p > .10$.

Table 1. 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.

Para.	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Para.1	Matching	20721.35[a]	636.58	19446.14	21996.56
	Mismatching	23088.40[a]	651.01	21784.27	24392.54
	Control	22709.16[a]	633.73	21439.65	23978.67
Para.2	Matching	13772.92[a b]	537.70	12695.78	14850.07
	Mismatching	16356.91[a]	549.90	15255.34	17458.48
	Control	15111.05[b]	535.29	14038.73	16183.38
Para.3	Matching	8811.29[a]	477.94	7853.85	9768.72
	Mismatching	11508.03[a]	488.79	10528.88	12487.18
	Control	10398.65[a]	475.81	9445.50	11351.81
Para.4	Matching	15199.14[a]	507.40	14182.70	16215.57
	Mismatching	16866.89[a]	518.90	15827.41	17906.38
	Control	16337.59	505.13	15325.70	17349.47
Para.5	Matching	14616.82[a]	694.44	13225.70	16007.94
	Mismatching	17755.33[a]	710.19	16332.65	19178.00
	Control	17613.62[a]	691.33	16228.72	18998.52
Para.6	Matching	24810.77[a]	1063.70	22679.92	26941.62
	Mismatching	30706.54[a b]	1087.83	28527.36	32885.72
	Control	27856.14[a b]	1058.94	25734.83	29977.46
Para.7	Matching	19744.12[a]	762.10	18217.45	21270.80
	Mismatching	20411.89	779.39	18850.59	21973.19
	Control	22251.69[a]	758.69	20731.84	23771.53
Para.8	Matching	10696.14	497.10	9700.33	11691.94
	Mismatching	10890.15	508.37	9871.75	11908.54
	Control	11340.05	494.87	10348.70	12331.41

Note: means sharing letter "a" within the same paragraph differ significantly at $p < .05$; means sharing letter "b" within the same paragraph show a trend toward significance ($p < .082$).

Implicit comprehension. A 3 (condition: matching *vs*. mismatching *vs*. control) between-participants ANOVA was conducted on the mean of agreement to 15 questions checking implicit comprehension of discourse. The results showed that there was no effect of pen condition on implicit comprehension of discourse, $F(2, 59) = 1.80, p > .10$.

GENERAL DISCUSSION

The present research was designed to test two major hypotheses derived from an embodied simulation account of language comprehension. First, we predicted that congruent emotional bodily states would facilitate online discourse comprehension. Second, we expected that details of emotion simulation would be retained after reading is completed, and thus could have an effect on offline processing of discourse.

The results showed that manipulation of emotional bodily state through facial posture had an impact on online discourse comprehension. It was 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) or prevented from it (mismatching condition). The facilitation effect also appeared to be enduring. Reading times in the matching condition were significantly faster than in the control condition when participants read and processed paragraphs one, three, five, six, and seven. Also, reading times in the matching condition were significantly faster than in the mismatching condition when participants read and processed paragraphs one, two, three, four, five, and six. The present results 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 emotion simulation affects online comprehension at higher levels than sentences.

It is also worth pointing out that a strong embodied hypothesis would predict both facilitation in the case when bodily systems are prepared for processing of congruent emotions (matching condition) and interference in the case when bodily systems are prevented from processing of emotion-congruent information (mismatching condition). Clearly, our data provide statistical evidence of facilitation, but none whatever of interference, given that the present findings do not show significant reading time differences between control and mismatching conditions. However, the fact 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 (see Figure 1) points to the conclusion that it may be premature to suggest that interference does not occur when suggested mood of the text is incongruent with the mood induced by the pen manipulation. Moreover, 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. Thus, further research is needed before final conclusions can be reached with respect to interference of discourse processing for the mismatching condition.

The findings reported in the present research also showed that the effect of emotion manipulation 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 may underlie 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, Havas, Becker, & Rinck, 2005, for a discussion of the related data including a factor of experiment half).

Finally, participants in the matching condition did not differ in their performance from participants in the mismatching condition and control condition with regard to offline comprehension measures. At the same time, increased reading speeds in the matching condition were not accompanied by poorer comprehension in offline measures, and thus cannot be easily attributed to a speed-accuracy tradeoff. First straightforward interpretation for null effects 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 have a long-term effect on comprehension processes. 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 present self-report paper and pencil questionnaire were too demanding for participants. Given this distinct possibility, it may be worthwhile to substitute such questions by types of measurement that rely on less complex memory processes. For

example, Pecher et al. (2009) demonstrated the role of sensorimotor simulations in offline sentence comprehension using recognition tasks. We are currently working on experimental procedures to incorporate similar tasks into discourse comprehension paradigm.

The present results demonstrate a positive effect of congruent emotional states on discourse comprehension. However, there may be alternative explanations for the reported results. 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 a 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 the proponents of simulation theory. For example, Havas et al. (2007) used an experimental procedure in their study to rule out the possibility that the interaction between pen condition and sentence valence could be explained by Bower's affect priming theory (1981, 1991). More precisely, the experimenters constructed pairs of words with the 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, the results of their 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 somewhat implicated in online 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 the present research with regards to "pen

between the teeth condition"[1].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) which showed that larynx muscles are activated during silent reading and that sub-vocal speech helps comprehension. While such an explanation is theoretically possible, we believe 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 study 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 at a more global discourse level.

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[1] The authors thank an anonymous reviewer for suggesting this alternative explanation. Indeed, although earlier results using both positive and negative sentence stimuli (Havas et al., 2007) were consistent with an embodied account rather than subvocalization process, no study has thus far differentiated between these two accounts on a more global discourse level. The present study was not designed to test this alternative hypothesis. Rather we sought insight into whether earlier findings using positive sentence stimuli fully generalize to paragraphs of text describing positive emotional events. Thus, to fully disentangle between subvocalization hypothesis and embodied account on discourse level, a similar experiment should be run with a text describing unpleasant or sad events.

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ANNEX A

Complete version of tutorial text in Portuguese with approximate English translation

Original text in Portuguese	Approximate English Translation
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."	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".
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.	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.
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.	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.
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-lo 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.	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.

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.	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.
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.	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.
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.	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.
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...	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…

ANNEX B

Complete version of target text in Portuguese with approximate English translation

Original text in Portuguese	Approximate English Translation
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.	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 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.
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.	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.
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».	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".
«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.	"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.

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.

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.

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.

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.

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.

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.

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.

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.