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Emotional language processing: How mood affects integration processes during discourse comprehension

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ABSTRACT

This research tests whether mood affects semantic processing during discourse comprehension by facilitating integration of information congruent with moods' valence. Participants in happy, sad, or neutral moods listened to stories with positive or negative endings during EEG recording. N400 peak amplitudes showed mood congruence for happy and sad participants: endings incongruent with participants' moods demonstrated larger peaks. Happy and neutral moods exhibited larger peaks for negative endings, thus showing a similarity between negativity bias (neutral mood) and mood congruence (happy mood). Mood congruence resulted in differential processing of negative information: happy mood showed larger amplitudes for negative endings than neutral mood, and sad mood showed smaller amplitudes. N400 peaks were also sensitive to whether ending valence was communicated directly or as a result of inference. This effect was moderately modulated by mood. In conclusion, the notion of context for discourse processing should include comprehenders' affective states preceding language processing.

1. Introduction

Feeling cheerful, satisfied, or gloomy is a common experience that can color much of our cognition: Research in psychology shows that mood has a pervasive effect on cognitive processes, in particular on judgment and memory. A positive or negative mood can influence cognitive processing in two different ways: it can facilitate processing of information whose content matches the mood's valence—the process our research investigates—or it can determine the processing strategy employed during task performance (stimulus-oriented and local for sad mood, heuristic-based and global for happy mood; for reviews, see Clore & Huntsinger, 2007; Martin & Clore, 2001). In the present study, we use EEG to investigate the impact of mood on discourse comprehension; in particular, how mood affects the integration of valenced information and how mood affects integration processes that depend on inferences. To date, little is known about the influence of mood on language processing beyond the single word, and in particular on discourse processing. As a result, the neural mechanisms by which mood affects linguistic processes are poorly understood.

Our hypothesis is that mood can influence semantic processing in the context of discourse comprehension, as mood constitutes a kind of emotional framing, though not a linguistic context. While theories of mood differ on the mechanisms that link mood to cognition, they agree in implicitly viewing mood as a form of context that can drive information processing. Indeed, it is because mood offers such a general context for all cognitive activity that its effect can be so pervasive. Mood's influence on cognition has in fact been documented in several domains, including social judgment, persuasion, memory, and attention (Clore & Huntsinger, 2007; Martin & Clore, 2001). Our own prior work has documented its effect in discourse comprehension (Egidi & Gerrig, 2009). Recently mood has also been shown to influence event-related potentials at the word and sentence level (Chwilla, Virgillito, & Vissers, 2011; Federmeier, Kirson, Moreno, & Kutas, 2001; Pratt & Kelly, 2008; Vissers et al., 2010).

Our investigation focuses on the N400 effect, as in discourse comprehension it often reflects the process of semantic integration of a critical word with prior context (for reviews, see Kutas & Federmeier, 2011; Lau, Phillips, & Poeppel, 2008). The N400 amplitude is larger for words that are less expected given prior context, thus suggesting that the N400 indexes the degree of difficulty involved in comprehension. Different types of contextual factors can have direct bearing on the meaning construction of a sentence. A first type of contexts are those that belong to the linguistic communication experience. These include contextual factors specific to language or semantic knowledge evoked by the text, such as general world knowledge and prior narrative context (e.g., Hagoort, Hald, Bastiaansen, & Petersson, 2004; van Berkum, Zwitserlood, Hagoort, & Brown, 2003). Other contexts that originate within the linguistic exchange and can affect the N400 are pragmatic factors auxiliary to the linguistic stream proper. Examples are

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co-speech gestures (e.g., *He slips on the roof and rolls down* accompanied by a gesture mimicking walking/rolling down; Habets, Kita, Shao, Özyürek, & Hagoort, 2010), speaker's voice (e.g., child's/adult's voice uttering the sentence *Every evening I drink some wine before going to sleep*; van Berkum, van Den Brink, Tesink, Kos, & Hagoort, 2008), and emotional intonation (e.g., positive/negative words preceded by a sentence uttered with congruent/incongruent prosody; Schirmer, Kotz, & Friederici, 2005). There are also extralinguistic contexts that can affect the N400, such as a comprehender's self-view or value system (van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009; Watson, Dritschel, Obonsawin, & Jentzsch, 2007). For example, self-referential words that are inconsistent with one's positive self-view elicit greater N400 than consistent words (Watson et al., 2007), and so does the word *good* (as compared to *bad*) in a sentence like *A society that condones abortion is a good society*, when the statement clashes with the comprehender's values (van Berkum et al., 2009).

We believe that mood is a context of the latter type; it originates outside the linguistic communication, is not language-specific, does not convey explicit linguistic information, and in the case of the comprehender's mood examined here, is not conveyed in the linguistic exchange examined. Instead, it constitutes a set of conditions on the receiver's side, under which all information is processed. Our theoretical stance is that mood can influence the integration process in discourse comprehension by creating constraints on what would be a fitting ending. Consistent with this hypothesis, mood has been shown to affect the N400 in sentence comprehension when it is used to induce different processing strategies (Chwilla et al., 2011; Federmeier et al., 2001). Federmeier et al. (2001) investigated the effects of positive and neutral moods on semantic memory organization by using sentence pairs. The study found that positive mood, as compared to neutral mood, was associated with a decrease in N400 amplitude between unexpected items of different categories (e.g., *They wanted the hotel look more like a tropical resort. So along the driveway they planted rows of pines/tulips*). Chwilla et al. (2011) studied the effect of happy and sad mood on high and low cloze-probability sentences (e.g., *the pillows are stuffed with feathers/books*) and found that the N400 effect was diffused over both hemispheres for happy participants, but limited to the right for sad participants. Both results are taken as evidence of mood-dependent processing styles, in line with research in other cognitive domains. Happy mood (as compared to sad or neutral mood) has been shown to facilitate semantic processing and increase the cognitive flexibility that leads to creative outcomes. Sad mood, on the contrary, promotes a narrow focus on external stimuli and analytic processing (Clore & Huntsinger, 2007; Davis, 2009; Isen, 1999). Consistently, the different scalp distribution of the N400 found by Chwilla et al. (2011) has been taken to reflect a more fluent integration process for the happy mood (see also Atchley, Ilardi, & Enloe, 2003 for processing emotional words). Unlike these studies, the present experiment does not test the impact of different moods as inducers of different processing strategies. Rather, it tests how moods affect the integration of differently valenced contents, making only minimal assumptions on processing styles differences between moods.

Our experiment investigates two aspects of the possible effect of mood on discourse comprehension. The first is whether mood facilitates the integration of textual information that matches the mood in valence, although this information is as consistent with prior context as mismatching information. The second is whether mood has a more general effect on discourse integration; in particular, whether it affects differently discourse integration that involves drawing an inference as compared to discourse integration that does not. Specifically, we used EEG to examine whether listeners' moods affect how they comprehend story endings, as measured by the amplitude and latency of N400 peaks. The moods we study are mild happiness, mild sadness, and a neutral mood, all induced experimentally. By *inducing a neutral mood* we refer to a situation in which both positive and negative mood valence were reduced by using a manipulation matched to that used for the induction of happy and sad moods, following a well-known practice in studies of the effect of mood on cognition (e.g., Forgas, 2007; Hänze & Meyer, 1998). Our first prediction was that mood biases comprehension so that content congruent with one's mood is easier to process. This would correspond to a mood congruence effect (Bower, 1981) that is often behaviorally reflected in facilitated processing and better memory for mood-congruent information and in the formulation of mood-congruent judgments and evaluations (Martin & Clore, 2001). Mood congruence has largely been shown when people experience mild happiness or sadness, and is typically defined by comparing the result patterns obtained for participants experiencing these two moods (e.g., Fiedler, Nickel, Muehlfriedel, & Unkelbach, 2001; Rowe, Hirsh, & Anderson, 2007). Because of this, prior studies cannot always determine whether mood congruence results from processing facilitation of congruent information or hindrance of mood incongruent information. Our study, however, included a neutral mood group that allowed addressing this issue.

In our experiment, participants in a happy, sad, or neutral mood listened to stories that could have either a positive or a negative ending (e.g., *Trev passed the exam*, vs. *Trev failed the exam*, as in the first story presented in Table 1). If comprehension is affected by mood, the N400 would show a pattern consistent with mood congruence: Happy participants would show a larger N400 for negative endings as compared to positive endings, and sad participants would show the opposite pattern, thus reflecting the contrast in understanding the story ending as incongruent, similar to typical N400 results. This hypothesis finds some support in a study by Chung et al. (1996) that reports a similar pattern, though in the context of a judgment task. The experiment examined the effect of happy and sad moods on the comprehension of a positive, negative or neutral word that concluded a very short story while participants made two evaluations: 1. whether the story turned out as they expected and 2. whether participants could identify with the story. The N400 was largest for inconsistent words, and larger for consistent words that mismatched the valence of the mood. In our experiment, we chose to study passive comprehension and did not ask participants to perform any judgment while they were listening to the stories. Our rationale was that, although some studies take judgment and passive comprehension as converging measures of language comprehension (e.g., Rapp & Gerrig, 2006; Rapp & Kendeou, 2007), others have shown that the two can yield different results and may therefore tap into different cognitive processes (Egidi & Gerrig, 2006, 2009). Neuroimaging studies also show that during language comprehension different tasks involve, at least partially, different functional networks (e.g., Ferstl & von Cramon, 2002; Kuperberg, Lakshmanan, Greve, & West, 2008).

Table 1
Examples of test stories used in the experiment.

Trev sat down in class for his psychology exam. He had studied hard, but he hadn't had time to cover all the topics. The professor liked to mix easy true/false questions with essay-type critical thinking questions. When the professor handed out the exams, Trev looked at the questions.
Positive sentence ending: He eventually passed the exam.
Negative sentence ending: He eventually failed the exam.
Anna wanted to cash her monthly check before the weekend so that she would have some money for a trip with her boyfriend. She forgot to cash it on Friday and wasn't sure that the bank would be open on Saturday. On Saturday morning, she drove to the bank.
Positive context ending: The doors were open.
Negative context ending: The doors were locked.

Our investigation extends to also explore the possibility of negativity bias in discourse comprehension and its relation with mood congruence. It is known that people show greater sensitivity to negative (as compared to positive) information in many domains of cognition (for a review, see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Negative stimuli are more informative than positive stimuli, are devoted greater attention, are detected faster, demand more elaborated and longer processing, and are remembered better. They also elicit different ERP responses than positive stimuli (Smith, Cacioppo, Larsen, & Chartrand, 2003; Olofsson, Nordin, Sequeira, & Polich, 2008). In discourse comprehension, negative story endings have been found to elicit longer reading latencies (like inconsistent endings do), a finding which has been taken as evidence of more careful processing or greater difficulty of integration (Egidi & Gerrig, 2009). In our study, negativity bias would be reflected in greater N400 peaks for negative endings compared to positive endings for participants in a neutral mood. Because of the expected negativity bias, the difference in participants' responses to positive and negative information may be similar for the happy and the neutral group.

Our aim was also to investigate the process that generates mood congruence in discourse comprehension and thus also distinguish it from negativity bias. We therefore tested whether mood congruence would show as easier processing of information congruent with the mood or more difficult processing of information incongruent with the mood, or both. Easier processing would show in a reduced N400 for mood congruent endings for happy and sad groups with respect to the neutral group. Conversely, greater difficulty would show in a larger N400 for mood incongruent endings for happy and sad groups with respect to the neutral group.

With respect to the topography of the effects of mood and text valence, we expected that the effects would be more frontally distributed. Not only are auditory N400 effects often shifted more frontally (Kutas & Federmeier, 2011), but processing emotional information has been shown to modulate the N400 at frontal sites (e.g., De Pascalis, Arwari, D'Antuono, & Cacace, 2009; Kanske & Kotz, 2007). This prediction is also supported by previous research demonstrating involvement of frontal areas in processing affect in general (e.g., Davidson, 2003) and mood in particular (e.g., Baker, Frith, & Dolan, 1997; Fitzgerald et al., 2011). Regarding lateral distribution, we considered that different moods alter the relative balance of left and right hemispheres contributions to language processing (Federmeier et al., 2001). Based on the results obtained by Chwilla et al. (2011), we therefore expected that the N400 effect would be widespread for the happy mood, but would be restricted to the right hemisphere for the sad mood.

Finally, we examined whether mood particularly affects language comprehension involving more substantial processing. It has been argued that mood more strongly influences processes requiring a substantive amount of information elaboration (e.g., Bower & Forgas, 2001; Forgas, 1995). In the current study, the valence of half of the story endings could be understood directly, whereas the other half could only be fully understood as a result of integration with prior context. We refer to the first type as *sentence endings*, and to the second type as *context endings*. Consider the two stories in Table 1. The sentence *Trev passed the exam* immediately communicates the positive quality of the ending, without having to refer this sentence to prior context. In contrast, the positive meaning of the sentence *The doors were open* can only be appreciated after assimilating it to the rest of the story and making the inference that open doors mean that the protagonist could cash her check. We examined whether mood affects this general valence implication variable. We considered that the fact that context endings are fully understood only after integration with a greater portion of linguistic context may have two consequences. First, compared to sentence endings, understanding context endings involves integration of a greater amount of information, which entails greater taxing and greater difficulty on the integration process. This may translate into greater N400 peaks for these endings. The second consequence is a delay in comprehending the valence of these endings, which could translate into a delayed N400 peak. In addition, to the extent that one type of ending valence or a mood can promote or hinder the integration process, either of these effects could be modulated by the valence of the endings or by participants' mood.

With respect to the scalp distribution of these effects, we considered that moods could have again the strongest effects frontally. In addition, because right hemisphere processing has been shown to be biased towards information maintenance in working memory (Kutas & Federmeier, 2000) different effects between moods on this variable could be mostly distributed to the right.

2. Method

2.1. Participants

Eighty-one undergraduates at the University of Chicago participated in this experiment for class credit or payment. They were all right-handed English native speakers. They were randomly assigned to one of the three mood groups (happy, sad, neutral). Six of these participants failed to follow the instructions or recalled less than 50% of the story endings; as a consequence, their data were not used in the analyses (see Section 2.5.1 for more details about this). The analyses reported here were performed on data from 75 participants, 25 for each mood group.

2.2. Materials

We used 6 video clips to induce moods and 82 test stories. Video clips ranged from 5 to 8 min in length. For the happy and sad mood inductions, we selected video clips that would be effective in making participants feel either cheerful or sad. For the neutral mood inductions we used clips that would distract participants from any initial affective bias they may have rather than elicit a specific affective response. We created 12 clips, 4 for each mood induction condition, and used the following norming procedure to identify the most effective clips. Nine undergraduates at the University of Chicago watched the clips in random order and filled out a questionnaire after each clip before moving to the next one. They rated whether the clip made them feel happy and whether it made them feel in a generally positive affective state. They also rated whether the clip made them feel sad and whether it made them feel in a generally negative affective state. We used this two-question procedure to ensure that the elicited mood was colored by happiness or sadness (and not, for example, by hope or anger) and that it was in fact a mood (a generally positive or negative affective state), rather than an intense emotion. Participants used a scale that ranged from 1 (*Not at all*) to 9 (*Extremely/Very much*). Based on their responses, we selected 2 clips for each mood induction. Table 2A shows the mean ratings for each question for the three types of clips selected for the experiment and demonstrates how the selected neutral, happy, and sad clips resulted in strongly different effects.

The test stories were 5–8 sentences long. The first few sentences introduced a scenario that was followed by one sentence stating either a positive or a negative ending. Each story had two versions: one with a positive ending and one with a negative ending. We constructed the stories so that each ending would be a natural conclusion and so that neither its positive or negative form could be predicted by the earlier context, on the basis of a norming study, as detailed below. Positive and negative endings of each

Table 2
(A) Results of the norming for the video clips selected for the experiment: mean ratings for each question and *t*-tests results. (B) Results of the mood induction check: mean mood ratings of the three mood groups at different times during the experiment. Both rating scales ranged from 1 (*Not At All*) to 9 (*Very Much*).

Questions	Mood Induction			*T*-tests		
	Happy	Sad	Neutral	Happy vs. Sad	Happy vs. Neu.	Sad vs. Neu.
(A)						
Experience happiness	6.77	1.23	3.67	10.73***	2.79*	−3.06**
Generally positive state	7.85	1.85	4.58	13.84***	3.49 *	−3.18**
Experience sadness	1	7.31	1.08	−11.37***	−1.07	10.26***
Generally negative state	1.15	7.46	2.16	−10.09***	−2.49*	7.32***

Mood induction	Question	Time during experiment			
		Before exp.	After Clip 1	After Clip 2	End of exp.
(B)					
Happy	Feel happy	5.76	7.28	7.48	6.00
	Positive mood	6.20	7.80	7.76	6.88
	Feel sad	1.40	1.08	1.08	1.24
	Negative mood	2.04	1.36	1.48	1.80
Sad	Feel happy	5.32	2.32	2.40	5.24
	Positive mood	6.04	3.17	3.54	5.80
	Feel sad	2.24	7.40	6.88	2.44
	Negative mood	3.08	6.88	6.38	3.44
Neutral	Feel happy	5.32	4.40	5.04	4.88
	Positive mood	6.24	5.84	5.84	6.04
	Feel sad	1.80	1.48	1.76	1.84
	Negative mood	2.56	2.32	2.52	2.40

Notes: df for Happy vs. Sad = 16, df for the other two = 15.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

story were very similar; only the last few words differed. Table 1 provides sample stories. Half of the positive and half of the negative story endings derived their valence from the meaning of the sentence itself (sentence endings) whereas half derived their valence from the implication the sentence conveyed in the context of the story (context endings). For each story, we balanced lexical and semantic overlap across versions. All ending sentences shared similar syntactic structure. We took these precautions so that it would be possible to compare the potentials elicited by these sentences. To ensure that participants would not find either ending more likely than the other given the context of each story, we normed the test stories with the procedure used in Egidi and Gerrig (2009). We distributed 98 candidate stories into two booklets so that each participant would see only the positive or the negative ending of each story. Twenty native English speaking undergraduates at the University of Chicago read each story without its ending. They then were asked to rate how surprising they found either the positive or negative ending for the story. The ending was presented below the question and was followed by a rating scale ranging from 1 (*Not surprising at all*) to 9 (*Extremely surprising*). To ensure that participants would use the entire range of the scale we added 30 filler stories, half of which were followed by obvious endings and half by unexpected endings. The distribution of positive and negative endings was counterbalanced and equated across questionnaires and the stories were presented in a different random order to each participant. Based on the norming data, we chose 82 stories such that the mean surprise ratings for the positive endings ($M = 3.68$) were similar to those for the negative endings ($M = 3.54$; $t(81) = -1.25$, $p = .216$). Half of these stories derived their valence from the sentence itself, and half from the integration of this sentence with its context. Within each of these groups the mean ratings for the positive endings was also similar to those for the negative endings (for the first group: $M_{pos} = 3.61$; $M_{neg} = 3.55$; $t(40) = -.43$, $p = .668$; for the second group: $M_{pos} = 3.74$; $M_{neg} = 3.53$; $t(81) = -1.34$, $p = .186$).

A speaker blind to the purpose of the experiment read the stories aloud and recorded them. Story endings were recorded separately from the stories, so as not to bias intonation in reading the story bodies as a function of the endings. We then identified acoustic onset of the critical words in the ending sentences for segmentation of the EEG during data analysis. The critical words were those that differed between the positive and the negative version of the endings for each story and determined the different meaning of the two versions of the sentence. Critical words were, for example, *passed*, *failed*, *open*, and *locked* in the sample stories presented in Table 1. In the experiment, all stories were presented as auditory stimuli and were read by the same male voice. Half of the stories were followed by positive endings and half by negative endings. We used a Latin square to distribute the stories to different lists in a counterbalanced fashion. Additionally, we used ten of the filler stories as practice stories to acquaint participants with the experimental procedure used during the EEG acquisition.

2.3. Design

After viewing the appropriate video clip to induce a happy, sad, or neutral mood, participants listened to stories with positive or negative endings that could derive their valence from the sentence itself or prior context. Thus, the design consisted of one between-participant variable: Mood (Happy, Sad, Neutral), and two within-participant variables: Ending Valence (Positive, Negative), and Valence Implication (Sentence, Context).

2.4. Procedure and EEG acquisition

The experiment consisted of two phases: A phase during which EEG data were recorded while participants watched video clips (mood induction) and listened to test stories, and a behavioral phase in which participants performed a recall task and completed several questionnaires.

In the first phase, participants sat in a sound-attenuating booth in front of a screen. We gave them a brief description of the experiment and the instructions about the EEG collection part. Because directing people's attention to their affective states may give rise to demand effects and trigger strategic processing that reduce the effects of mood (Berkowitz, Jaffee, Jo, & Troccoli, 2001; Martin, 1990), and because we intended to obtain unbiased replies to several questions relating to participants' mood after the study, we did not inform participants about the mood manipulation until the end of the experiment. Instead, we told participants that the experiment investigated how people comprehend language in two situations: when both visual and auditory information is available and when only auditory information is available. They would watch some video clips and listen to some stories while an EEG apparatus would record the electrical activity on their scalp. We asked participants to follow both clips and stories for comprehension and to not blink or move their eyes when a cross appeared on the screen during the presentation of the stories, following a procedure used by van Berkum et al. (2003). Before electrode application, participants engaged in a brief practice of this procedure. Once the electrode net was in place, the experiment began with the presentation of the first mood-inducing clip, followed by the first block of stories. The procedure of the story presentation was as follows: Each trial consisted of a 300 ms warning tone, followed by 700 ms of silence, followed by the story body. At the end of the story body we introduced a 1000 ms pause, followed by the presentation of the ending sentence. The pause approximated natural pausing times in the speech stream of the story and was not perceived as interrupting the speech flow. The ending was followed by 3500 ms of silence before the warning sound announced the next story. A cross also appeared on the screen at the beginning of the pause before the ending sentence and disappeared 1500 ms after the presentation of that sentence. After presenting the first 20 or 21 stories, to refresh participants' induced mood, we showed a still of the video clip participants had watched at the beginning. After 5 s the following question appeared at the bottom of the screen: "What was this clip about? We will ask you to give us your answer later". Both still and question remained on the screen for an additional 10 s and were then followed by a second group of 20 stories. At the end of this section, we gave participants the chance to rest and make small movements for a couple of minutes, then repeated the same procedure with a different video clip (which induced the same mood) and the rest of the stories. We presented all stories in a different random order for each participant.

We recorded EEGs using a 128-channel Geodesic Sensor Net with a sampling rate of 250 Hz. We kept channel impedance below 40 kΩ and referenced all channels to the vertex channel (Cz) during recording. We recorded EEG continuously during the presentation of stories and endings, and amplified the EEG recordings using a filter with high cutoff of 100 Hz and a low cutoff of .1 Hz.

After participants finished listening to the stories and were freed of the EEG net, we tested whether they had paid attention to the material presented to them during the EEG phase. After a 10-min filler task, participants completed a recall task assessing their memory of the clips and the stories. They first described the general subject and the most salient part of each video clip. Next, we presented participants with the text of each of the stories and asked them to write how each story ended. As a final task, participants completed a survey about the experiment they had just completed, which contained several questions assessing the success of the mood induction. The critical questions asked participants whether they were feeling happy, sad, in a positive mood, or a negative mood at four times during the experiment; namely, when they arrived at the lab, after watching the first clip, after watching the second clip, and while they were completing the questionnaire. Participants gave their responses on a scale ranging from 1 (*Not At All*) to 9 (*Very Much*). The other questions were fillers introduced to minimize demand effects on the mood ratings. Finally, immediately before the debriefing, we asked participants what they thought the study was testing. We intended this brief interview to assess whether participants had had any intuition about the experimental manipulation of mood. None of them reported any.

2.5. Data analysis

2.5.1. Recall

We coded participants' recall of the endings of the stories they listened to only to assess how carefully participants paid attention to the stories. In each ending we identified one meaningful unit capturing an idea that could be easily remembered as a whole (e.g., *the doors were locked, Trev passed the exam*; as in O'Brien and Albrecht, 1991). One coder, blind to the participants' mood condition, assigned one point to each idea fully or partially recovered and zero points to missing ideas, misrecalls, and guesses (e.g., *it all went well*). From the codes thus obtained, we created a percentage score. We were thus able to remove from subsequent analyses data from 4 participants who remembered less than 50% of the endings. Three of them belonged to the neutral group and one to the happy group.

2.5.2. EEG

We filtered continuous EEG data with a high cutoff filter of 30 Hz (zero-phase, 6 db/oct). We then re-referenced the data to the average reference, and segmented EEG data into epochs starting 300 ms before and ending 1000 ms after the critical word onset (CWO) in the ending sentence. We used an algorithm to isolate eye movements and blinks artifact (with a threshold for of 150 μV for horizontal eye movements and 250 μV for vertical eye movements) and removed these and other artifacts manually during averaging. This procedure resulted in a loss of 4.8% of segments (8% for the neutral mood group, 4.5% for the sad mood group, and 1.9% for the happy mood group). During averaging, we subtracted from each channel a baseline calculated over the 200 ms before CWO. The averages for each condition were weighted by the number of epochs that contributed to their calculation. We grouped the net sensors into 9 groups (regions) according to the typical frontal/central/parietal (F, C, P) and left/center/right (L, C, R) partitions but excluding the most peripheral electrodes. Each group included a minimum of 9 and a maximum of 12 electrodes. Fig. 1D shows a graphical depiction of the sensor grouping. In what follows, we refer to the frontal groups as LF, CF, and RF; to the central ones as LC, C, RC; and to the parietal ones as LP, CP, RP. We then extracted peaks from the time window most suitable for the study of N400 peaks: between 300 and 500 ms after CWO. Within this time window we identified both the peak amplitude and its latency, per each condition and each sensor. Given that the dense EEG array positions sensors closely to each other, we could average these peak parameters over all electrodes in each region, to increase signal-to-noise ratio. We performed all statistical analyses with participants as a random factor.

To study the effect of the three moods on the peaks of the N400 we first conducted two general omnibus anovas for all the sensors, one on the maximal peak amplitudes and one on the latencies of those peaks. These analyses had the purpose of giving a general idea of the effects in our data. Participants' Mood (Happy, Sad, Neutral) was used as a between-participant variable with 3 levels; Ending Valence (Positive, Negative) and Valence Implication (Sentence, Context) were used as within-participant variables with 2 levels. To allow for a certain degree of localization of the effects without increasing the complexity of the design by adding new variables, we also performed two sets of omnibus anovas per each region, one on maximal peak amplitudes and one on peak latencies. These anovas used the same variables and levels as the general omnibus.

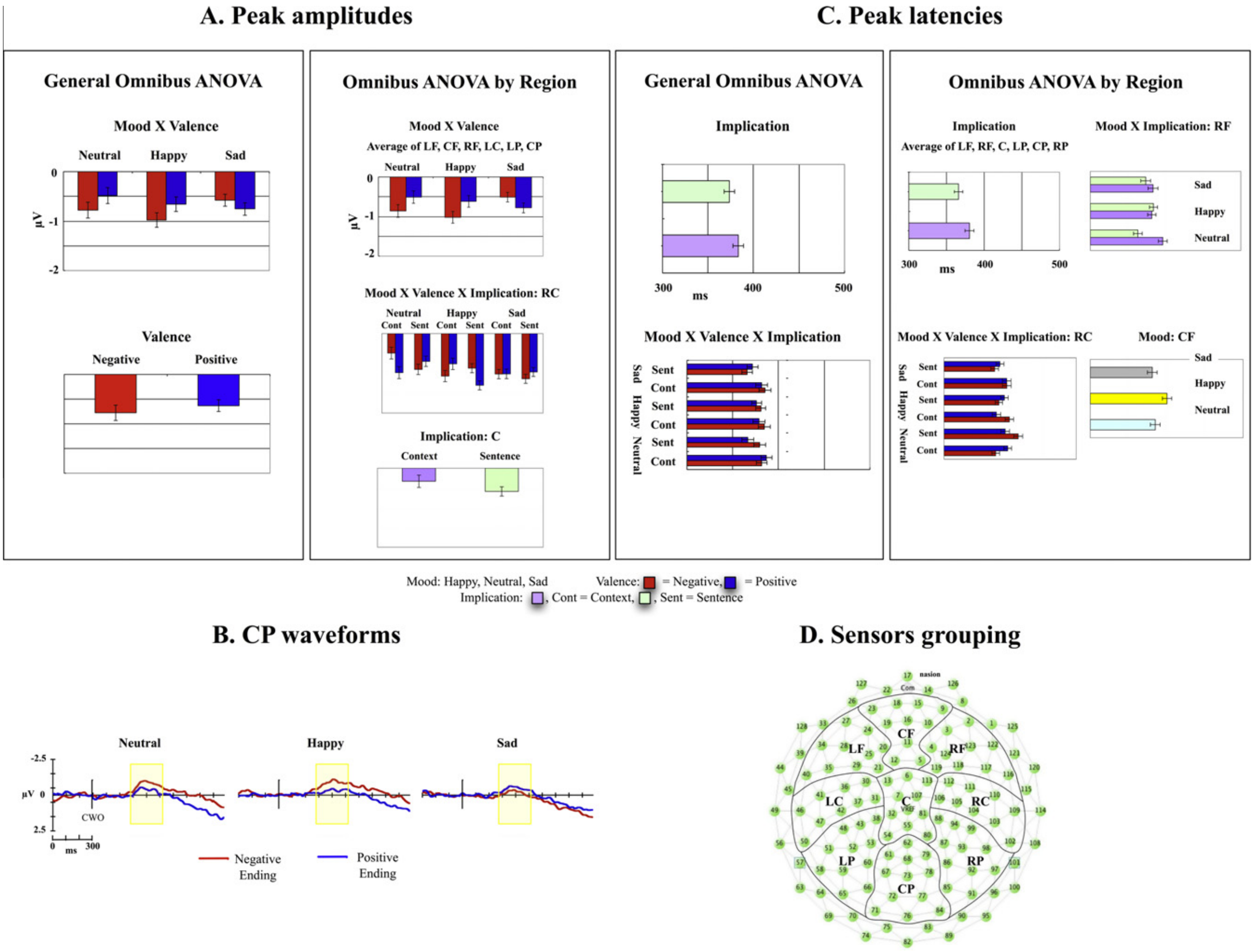

Fig. 1. (A) Means of the reliable effects identified by the general omnibus anova and the ombnibus anovas by region on peak amplitudes and (B) on peak latencies. (C) Waveforms of the centro-parietal region (CP) for each of the three moods, collapsed over the implication variable. (D) Sensor grouping into regions.

To investigate whether mood congruence occurred between happy and sad mood groups, we compared the peak amplitudes of these two groups in a separate anova (Mood (2) × Valence (2) × Implication (2)). To understand whether the pattern of mood congruence of the happy mood group would differ from that of negativity bias of the neutral mood group, we also performed an anova that compared the peak amplitudes of these two moods (Mood (2) × Valence (2) × Implication (2)). To determine whether mood congruence would show as easier processing of mood congruent information or more difficult processing of mood incongruent information, we performed *t*-tests that compared peak amplitudes of positive and negative information (separately) for happy and neutral moods, and for sad and neutral moods. We performed these tests only in the regions in which the omnibus anovas had indentified an interaction involving Mood and Valence.

3. Results

3.1. Mood induction

At the end of the experiment, participants rated their happiness, positive mood, sadness, and negative mood in four occasions during the experiment: at their arrival to the lab (T_0), after watching the first clip (T_1), after watching the second clip (T_2), and at the end of the experiment (T_3). Table 2B shows the mean ratings for each question. To assess the success of the mood induction we performed two sets of *t*-tests. We first compared participants' ratings at T_0 with those given at T_1, T_2, and $T_{3,}$ to test whether participants' mood was effectively modified by the presentation of the videos and whether this modification lasted until the end of the experiment. Table 3A shows the results of these tests. The second set of *t*-tests assessed whether participants in the different groups were experiencing different moods throughout the experiment. We compared the ratings given by the participants in the positive and the sad groups with the ratings of the participants in the neutral group. This analysis was necessary because, although the previous set of *t*-tests had already shown that the presentation of the video clips polarized ratings, it did not guarantee that they were different across groups. Table 3B shows the results of these tests. On average participants in the three groups arrived at the experiment with the same medium level of happiness and good mood and low level of sadness and negative mood. Participants who watched the neutral video clips maintained this pattern throughout the experiment. Only after watching the first clip did their happiness and sadness decrease slightly. Participants who watched the happy clips experienced an increase in happiness and good mood and a slight decrease in sadness and negative mood after watching the clips, but not at the end of the experiment. Participants who watched sad clips experienced a considerable decrease in happiness and good mood and an even stronger increase in sadness and negative mood after watching the two clips, but this effect did not last until the end of the experiment. The three groups were experiencing significantly different levels of happiness, good mood, sadness, and negative mood throughout the experiment. Although

Table 3
(A) Results of *t*-tests comparing how participants' mood ratings differed at different times of the experiment from their mood ratings at their arrival in the lab. (B) Results of *t*-tests comparing whether mood ratings of participants in the happy and sad mood groups differed from those of the neutral mood group at different times during the experiment.

Question	Before exp. vs.	Mood induction		
		Happy	Sad	Neutral
(A)				
Feel happy	After Clip 1	−3.04**	6.50***	3.48**
	After Clip 2	−3.72***	7.16***	0.85
	End of exp.	−0.77	0.22	1
Positive mood	After Clip 1	−4***	5.91***	1.08
	After Clip 2	−3.64***	4.98***	0.46
	End of exp.	−1.61	0.71	0.49
Feel sad	After Clip 1	2.14*	−9.55***	1.88$^{*\wedge}$
	After Clip 2	2.14*	−10.39***	0.17
	End of exp.	1.16	−0.56	−0.24
Negative mood	After Clip 1	2.53*	−6.33***	0.63
	After Clip 2	2.35*	−5.57***	0.1
	End of exp.	0.67	−1.1	0.38

Time during experiment	Question	*T*-tests against neutral mood	
		Happy	Sad
(B)			
Before exp.	Feel happy	0.89	0
	Positive mood	−0.08	−0.38
	Feel sad	−1.39	1.04
	Negative mood	−1.06	0.91
After Clip 1	Feel happy	6.41***	−5.33***
	Positive mood	4.04***	−5.10***
	Feel sad	−2.30*	16.61***
	Negative mood	−2.61*	9.79***
After Clip 2	Feel happy	5.34***	−6.44***
	Positive mood	3.42***	−5.05***
	Feel sad	−2.50*	12.85***
	Negative mood	−2.49*	7.77***
End of exp.	Feel happy	2.16*	0.76
	Positive mood	1.72$^{*\wedge}$	−0.51
	Feel sad	−1.93$^{*\wedge}$	1.50
	Negative mood	−1.33	2.00*

Notes: df = 24 for Table 3(A).
df = 48 for Table 3(B).
* $p < .05$.
** $p < .01$.
*** $p < .001$.
$^{*\wedge}$ $p < .05$ one-tailed.

Table 4
(A) Results of the omnibus anovas (Mood (3) × Valence (2) × Implication (2)) on peak amplitudes and latencies for each region. (B) Results of the two anovas (Mood (2) × Valence (2) × Implication (2)) on peak amplitudes that compared happy and sad groups and happy and neutral mood groups. The *p* value is <.05 unless otherwise specified.

	Effect	Region	*F*	MSe
(A)				
Peak amplitudes	M × V	LF*	5.04	.800
		CF	3.69	.781
		RF*	5.78	.625
		LC	3.87	1.01
		LP	4.17	.855
		CP*	6.55	1.45
	V	CF*	7.57	.781
		RF	5.59	.625
	M × V × I	RC	3.89	.847
	I	C	4.09	1.20
Peak latencies	I	LF*	10.72	1404.91
		RF*	7.53	1821.20
		C	5.47	1968.20
		LP*	10.71	1774.91
		CP**	12.37	1678.72
		RP*	7.15	2058.53
	M	CF*	5.16	2024.10
	M × I	RF	4.43	1821.20
	M × V × I	RC	3.55	2019.50
(B)				
Moods compared				
Happy vs. Sad	M × V	LF*	9.62	.755
		CF*	7.17	.723
		RF	5.42	.553
		LC	5.88	1.26
		CP*	9.62	1.77
		RP	4.55	.909
	M × V × I	RC	5.14	.499
Happy vs. Neutral	V	LF*	7.32	1.06
		CF*	11.27	.992
		RF**	15.55	.537
		CP*	10.24	1.67
		RP	6.31	.926
	M × V	LC	4.08	.899
	M × V × I	C	4.67	1.10
		RC	6.05	1.07

Notes: M = Mood, V = Valence, I = Implication.
Interactions dfs = 2,72, Main effects dfs = 1,72 for Table 4(A).
dfs = 1,48 for Table 4(B).
* $p < .01$.
** $p < .001$.

at the end of the experiment each mood group gave ratings that did not differ from those given at the beginning, the difference in ratings across groups was maintained, at least partially, until the end of the experiment. The positive group was still happier, in a better mood, and less sad than the neutral group (but did not differ in negative mood), whereas the sad mood group was still (and only) in a more negative mood.

3.2. Analysis of peak amplitudes

3.2.1. General analysis

The analyses of the peak amplitudes showed a pattern of negative peaks consistent with the configuration of the auditory N400 (e.g., van Berkum et al., 2003; Wu & Coulson, 2010). Fig. 1A and B show the means of the reliable effects and grand average waveforms for a representative region, CP. Fig. 1A also shows the means of the reliable effects by region. To ease presentation, effects that occur in more than one region are averaged in one graph; however, Fig. 3A in the Supplementary Material shows the pattern of the effects for each scalp region. Table 4A shows the results of the omnibus anovas by region.

The results of the general omnibus anova revealed an interaction between mood and ending valence ($F(1,72) = 6.70$, $MSe = .295$, $p < .01$) which showed a similar pattern for happy and neutral moods, where negative endings were associated with greater peaks. It also showed an inverted pattern for the sad mood, where positive endings showed larger peaks than negative endings. There was also an effect of valence ($F(1,72) = 5.18$, $MSe = .295$, $p < .05$) due to the fact that negative endings showed larger peaks than positive endings.

The omnibus anovas by region showed an interaction between mood and valence in 6 regions: the three frontal ones, LC, LP and CP which again demonstrated a very similar pattern for the happy and neutral mood groups, where negative endings showed larger (or equal) peaks than positive endings, and an opposite pattern for the sad mood group, where positive endings showed larger peaks than negative endings. Furthermore, the central region showed a main effect of integration, and RC showed an interaction between mood, valence, and implication (discussed more in detail in Section

3.2.4). In addition to the interaction, the omnibus anova also found a main effect of valence in LF and CF due to the fact that negative endings showed peaks of greater magnitude than positive endings. There was no main effect of mood.

3.2.2. Mood congruence between happy and sad moods

The first issue our experiment was designed to test was whether mood would be associated with a pattern consistent with mood congruence for participants in a happy and a sad mood. Such pattern would be seen in larger N400 peaks for information whose valence mismatches the mood. The anovas that directly evaluated pair-wise differences between the happy and sad groups (Mood (2) × Valence (2) × Implication (2)) found that peak amplitudes of the happy and sad groups differed reliably as a function of the valence of the story ending: The interaction between mood and valence reached significance in the three frontal regions, LC, CP, and RP (as shown in Fig. 2A and Table 4B). In these regions, the data pattern showed greater N400 amplitude for mood mismatching content. For the happy mood group, peak amplitudes of positive endings were reduced with respect to those of negative endings, and the converse pattern was found for the sad group. Thus, both groups were sensitive to the difference in ending valence, indicating that the interaction between mood and valence was driven by responses in both groups.

3.2.3. Dissociating negativity bias from mood congruence for happy and neutral moods

The second issue our experiment was designed to examine was whether the mood congruence shown by the happy group differed from the pattern of negativity bias (i.e., increased N400 for negative information) of the neutral group. The analysis that compared the amplitudes for the happy and neutral groups (Mood (2) × Valence (2) × Implication (2)) revealed a reliable interaction only in LC—due to the fact that in that region the peaks for positive and negative endings were equal for the neutral group—and found a main effect of valence in the three frontal regions, CP, and RP, thus suggesting that the two groups did not diverge strongly in their response to positive and negative information (as shown in Fig. 2B and Table 4B). Thus, while positive and negative endings were processed differently, peak amplitudes showed a very similar pattern for the neutral group's negativity bias and the happy group's mood congruence.

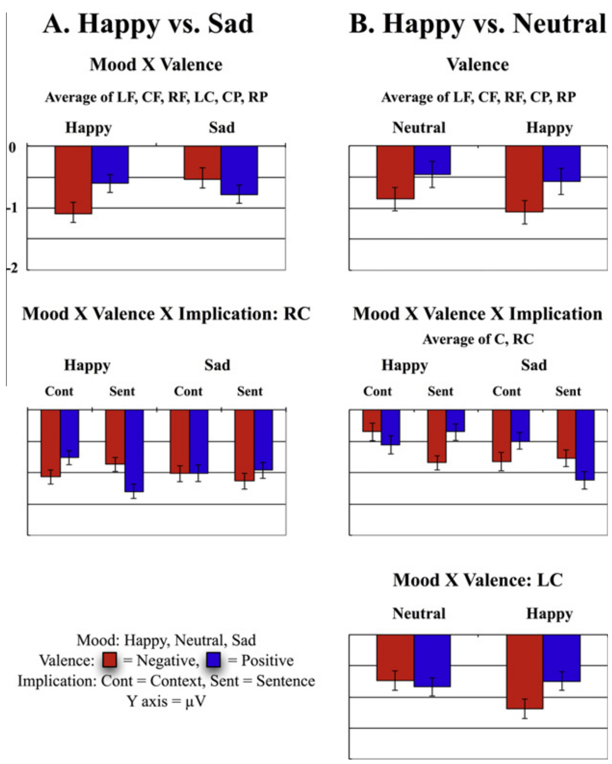

Fig. 2. (A) Peak amplitude means by region of the reliable effects identified by the anova comparing the happy and the sad mood groups and (B) of the reliable effects identified by the anova comparing the happy and the neutral mood groups.

3.2.4. Mood congruence as facilitated or more difficult processing

The third issue addressed by our experiment was whether mood congruence would manifest as facilitated processing of mood congruent information or as more difficult processing of mood incongruent information. The analysis that compared peak amplitudes of negative endings for happy and neutral groups revealed that in LF and LC happy mood was associated with larger peaks (LF: $M_{HAPPY} = -0.964$, $M_{NEU} = -0.567$, $t(48) = -1.847$, $p < .05$, one-tailed; LC: $M_{HAPPY} = -1.190$, $M_{NEU} = -0.736$, $t(48) = -1.993$, $p < .05$, one-tailed). The analysis on positive endings, however, found no differences ($ps > .15$). For happy mood, then, mood congruence was manifest as more difficult processing of mood incongruent information.

The analysis that compared negative endings for sad and neutral groups revealed that in RF, RC, and CP negative peaks were reduced for sad participants (RF: $M_{SAD} = -0.381$, $M_{NEU} = -0.885$, $t(48) = 2.645$, $p < .05$; RC: $M_{SAD} = -0.700$, $M_{NEU} = -1.079$, $t(48) = -2.106$, $p < .05$; CP: $M_{SAD} = -0.207$, $M_{NEU} = -0.886$, $t(48) = -2.598$, $p < .05$). The analysis of positive endings, however, found no differences ($ps > .15$). Thus, for sad mood, mood congruence resulted from facilitation in processing mood congruent information. In general, mood congruence was mostly driven by differential processing of negative information.

3.2.5. Impact of valence implication

In order to test whether mood would affect the integration process in a more general way, we examined how the implication variable affected peak amplitudes. Recall that we refer to the endings that directly communicated a positive or negative meaning as *sentence endings* and those that derived their valence from the integration of the ending with prior context as *context endings*. The omnibus anovas revealed two regions sensitive to this variable (see Fig. 1A and Table 4A). Specifically, the central region C showed that sentence endings were associated with greater peak amplitude than context endings. In addition, RC showed an interaction between mood, valence, and implication. This interaction was also found in the comparison of the happy and the sad groups, and in the comparison of the happy and the neutral groups (Fig. 2A and B, Table 4B). This suggests that in this region the three moods were differently sensitive to whether the valence of the endings was understood directly or via an inference. The comparison between the happy and the neutral mood, but not that of the happy and sad mood, also revealed the presence of this three-way interaction in the central region (C).

3.3. Analysis of peak latencies

3.3.1. General analysis: the impact of mood and valence implication

The analyses of the peak latencies showed that in each region the N400 peaked within a 50 ms window, between 350 and 400 ms after CWO. Fig. 1C shows the means of the reliable effects and Table 4A shows the statistical results of the omnibus anovas by region. In Fig. 1C, effects occurring in more than one scalp region are averaged in one graph, but Fig. 3B in the Supplementary Material shows the pattern of the effects for each region.

The general omnibus anova revealed a main effect of ending implication ($F(1,72) = 13.51$, $MSe = 534.86$, $p < .001$) which showed that context endings were associated with a later peak. There was also a three-way interaction between mood, valence, and implication ($F(1,72) = 4.43$, $MSe = 301.95$, $p < .05$), indicating that moods affected in a different way participants' response to the valence of the endings and to the way this valence was communicated.

The variable that influenced peak latencies the most was valence implication: The omnibus anovas showed that 6 regions—the two frontolateral ones (LF, RF), the central one (C), and the 3 parietal ones—demonstrated a main effect of implication. In these regions, peaks showed a consistent pattern: They occurred earlier for sentence endings than for context endings. This delay of the context ending peaks was expected, because the valence of these endings could only be understood during or after integration of the sentence with prior context.

The omnibus anovas also showed that mood had an impact on the temporal occurrence of N400 peaks in CF, RF and RC. In CF, it revealed a main effect of mood, because the peak latencies for the happy mood group occurred later than those of either of the other two mood groups. In RF, in addition to the main effect of integration, the omnibus anova revealed an interaction between mood and implication suggesting that the impact of the implication variable was greatest for participants in a neutral mood. Finally, in RC, the anova revealed a 3-way interaction. The pattern of results shows greater similarity between the patterns of peak latencies for the happy and sad groups. This result seems to imply that departure from neutral mood, in any direction (happy or sad), is the determining factor in this region.

4. Discussion

Our experiment shows that mood affects discourse comprehension by functioning as a general context, a set of constraints, or a filter, on comprehenders' information processing. Therefore, the construction of consistency in discourse processing is sensitive to contextual cues well beyond the immediate linguistic context in which a linguistic exchange takes place. This has several implications for mood and language comprehension theories.

4.1. Mood congruence and negativity bias

According to the prevalent view of the N400 effect in discourse, larger N400 amplitudes reflect greater difficulty of integration (e.g., Hagoort, 2008; Kutas & Hillyard, 1980). Based on this interpretation, our findings show that content that is congruent with one's mood is easier to integrate and possibly easier to understand. This was seen in a mood congruence effect: Endings that matched participants' happy or sad mood evoked smaller N400 peaks.

The current experiment also found that the semantic property of text valence had a similar effect on the integration process for both neutral and happy moods. Negative information was more difficult to integrate: happy and neutral groups showed larger N400 peaks for negative endings. It is important to recall that positive and negative endings were normed to be equally probable conclusions for the stories and therefore the difference in N400 amplitudes cannot be attributed to different predictability of positive and negative endings in relation to prior context.

The similarity between the pattern of results of the neutral and happy groups suggests that the cognitive mechanisms leading to increased sensitivity to negative information in the two moods may be analogous (note, also, that studies of negativity bias do not test participants' mood level and do not typically consider the possibility that participants' affective states may be a factor in driving the effect). Despite this similarity the happy group showed mood congruence as an increased difficulty in processing negative information beyond negativity bias, and no facilitated processing of positive information. Sad mood, in contrast, clearly overcame the negativity bias and resulted in an opposite pattern in which negative endings were easier to process. For the sad mood, congruence was the result of easier processing of negative information and no increased difficulty in processing positive information. Mood congruence therefore originated from differential processing of negative information only.

Mood congruence is often described as facilitated processing, and the few studies on language processing that study mood congruence seem to support this view. These studies, however, focus on single-word processing as studied through lexical decision and word naming (e.g., Ferraro, King, Ronning, Pekarski, & Risan, 2003; Niedenthal, Halberstadt, & Setterlund, 1997) which do not involve integration. Our study is the first one to show that, in discourse comprehension, mood congruence is driven by happy and sad moods' differences in processing negative information. This, and the fact that the effect is mostly lateralized to the left for happy mood and to the right for sad mood suggests that the cognitive processes behind mood congruence are likely to be different for the two moods. Sad mood, for example, might induce reliance on a more extended association network for negative information than happy mood, or sad mood might prompt increased readiness to negative outcomes as compared to happy mood. Our results, however, do not allow going beyond these speculations; further research is necessary to fully understand the processes behind moods' influences on the comprehension of negative information in discourse.

With respect to the study by Chung and colleagues (1996; C96 from now on) mentioned in the introduction—the only study in the N400 literature that investigated the effect of mood on cognition by using discourse—our results are consistent with the pattern of mood congruence reported there: a larger N400 for endings incongruent with participants' mood. In addition, that study reported an increased late positivity for mood-incongruent endings, which is absent in our results. As this effect is usually taken to reflect processes of revision (e.g., Kuperberg, 2007), we suggest that this type of process was more likely to occur in the C96 study than in ours. Two factors in particular suggest that this may be the case. First, the C96 study made comprehension subservient to an evaluation process by asking participants to comprehend the critical word while performing a judgment of fit of the ending with the rest of the story. Second, the C96 study employed self-paced presentation of the critical word and asked participants to voluntarily adopt and maintain a certain mood. These factors may have made the adoption of a revision process very likely, by increasing both the saliency of the critical word and its relation to the mood manipulation. In contrast, our experiment differed in that participants were only required to passively listen to the stories, which were presented auditorily in a continuous stream of input where critical words were not marked with respect to other words, and our participants were induced to experience moods in an implicit way. Our results therefore suggest that the revision process may not be intrinsic to the influence of mood on discourse integration.

4.2. Integration processes and their modulation by mood

The inclusion of the integration variable allowed us to evaluate general effects of discourse integration demands on the N400, and evaluate their modulation by mood. Both analyses of peak latencies and peak amplitudes have important implications for a better understanding of the neural processes indexed by the N400 effect. N400 latencies have been shown to be affected by factors such as language proficiency: The lower the proficiency of a bilingual or of a child, the later the peak occurs (Ardal, Donald, Meuter, Muldrew, & Luce, 1990; Holcomb, Coffey, & Neville, 1992; Moreno & Kutas, 2005). The delay our experiments documents for peaks evoked by context endings (as compared to sentence endings) suggests that the range of endogenous factors that can affect the N400 latencies is more extended. In our task, delayed peaks likely indicate the presence of a more taxing integration process, due to either difficulty in retrieving relevant information or difficulty in manipulating a greater amount of contextual information during the integration process.

In discourse comprehension, N400 amplitudes are usually taken to reflect semantic integration processes, which are referred to as *binding* (Federmeier & Laszlo, 2009) or *unification* (Hagoort, Baggio, & Willems, 2009) and which construct a novel representation of the text that is not already stored in memory. Among the alternative explanations proposed, the most accredited is that the N400 reflects access to lexical information (e.g., Kutas & Federmeier, 2000; Lau, Almeida, Hines, & Poeppel, 2009). According to this interpretation, modulations of the N400 occur because context promotes activation of relevant lexical information, thus facilitating lexical access of certain words and hindering that of others. Although there are several cases in which this account holds (e.g., Lau et al., 2009; see also Kutas & Federmeier, 2011), this mechanism cannot explain the results of the present experiment. In fact, if mood only facilitated lexical access of mood congruent critical words (or hindered the access of mood incongruent words), mood would have only modulated the processing of sentence endings (i.e., the stimuli that directly communicated negative or positive information), but not the processing of context endings which contained no lexical content related to mood. That is, context would have prepared listeners to words such as *passed* and *failed* in the sentence endings, but much less so to words like *open* and *closed* contained in the context endings. However, we find that mood affected both sentence and context endings, as shown by the mood by valence interactions found in the analyses of the peak amplitudes (and by the lack of a three-way interaction, suggesting that there was a similar mood by valence interaction for context and sentence endings). In fact, when we analyzed the peak amplitudes of the context endings separately from the sentence endings we also found a significant interaction between mood and valence in four regions (LF: $F(2,72) = 5.05$, $MSe = 0.69$, $p < .01$; LC: $F(2,72) = 5.22$, $MSe = 0.99$, $p < .01$; CP: $F(2,72) = 9.76$, $MSe = 1.49$, $p < .01$; RP: $F(2,72) = 3.14$, $MSe = 1.16$, $p < .05$). This conclusively shows that mood congruence is also found in cases where the valence of a sentence is not determined directly through lexical access, but is strongly dependent on integration.

Our experiment also tested whether mood interacted with the implication variable, which would suggest a relation between mood and general semantic integration processes. Mood interacted with this variable in affecting peak amplitudes and latencies of the N400. This result suggests that the happy mood is the most sensitive to the different integration demands of the endings, but the result of the peak latencies suggests that the neutral mood is the most sensitive one. In addition, frontally in the center, peak latencies for the happy mood group occur later than for the other two mood groups. Although these interactions do not depict a univocal picture, they suggest that different moods are differently sensitive to the process involved in inference operation by which the meaning of the ending is derived. This result is however preliminary and further research is necessary to understand how and to which extent mood influences these two ways of constructing the valence of a sentence.

4.3. Scalp distribution and processing differences between moods

Although the complexity of our design does not allow performing anovas that include scalp sites as a variable (e.g., front vs. back or left vs. right) as these would require great statistical power, some conclusions on the distribution of the effects across the scalp can be drawn from the analyses performed on the 9 regions. We had predicted that the effects of mood would be more evident in frontal regions, consistent with the literature showing a frontal shift of the N400 in processing affective stimuli (e.g., Kanske & Kotz, 2007) and the literature demonstrating involvement of frontal areas in processing affect (e.g. Davidson, 2003). The results of the peak amplitudes were consistent with the prediction; those of the latencies were only partially consistent, because the effect of mood did not extend to the left, but extended to the centro-right region. The effect of implication was however widely distributed, and was lacking only centrally on the left, which may indicate a greater involvement of the right hemisphere in a process that requires maintenance in working memory of a greater amount of information (Kutas & Federmeier, 2000).

With respect to the lateral scalp locations, we had expected a more widely distributed effect of the happy mood, and an effect limited to the right hemisphere for the sad mood. These predictions were based on evidence showing that the two moods promote different processing styles (Davis, 2009; Martin & Clore, 2001) and that these, during sentence integration, translate in a reduced involvement of the left hemisphere for the sad mood (Chwilla et al., 2011). This difference was not however evident in any of the analyses; both the omnibus anova and the comparisons of the different moods groups showed that the effects were quite distributed. Only the test to evaluate whether mood congruence was a result of easier or more difficult processing revealed that 1. the distribution was more lateralized for happy mood and 2. mood congruence was left-lateralized for happy mood and mostly right-lateralized for sad mood. Because this pattern reveals differential processing of negative information only, the stronger lateralization for the happy mood may occur because the process required by the negative information alone may be narrower than the one usually required for neutral and positive information, or may be based on a less extended association network. Although our data do not allow us to determine the specific differences in processing negative information between the two moods, there are hemispheric asymmetries, especially frontally, in processing negative and positive information which could be responsible for the effect (Murphy, Nimmo-Smith, & Lawrence, 2003; Phan, Wager, Taylor, & Liberzon, 2002). Specifically, left and right prefrontal and orbitofrontal cortices (PFC and OFC) process differently valenced stimuli and moods differently: both PFC and OFC are more likely to respond to positive affect on the left, and are more likely to respond to negative affect on the right (e.g., Davidson, 2003; Davidson & Irwin, 1999).

4.4. The importance of implicit mood

Our experiment studied the effect of moods of which people are not aware and therefore cannot be focused on. The fact that we obtained modulations of the N400 by inducing mood implicitly is significant. It shows that our effects were directly driven by people's mood rather than their subjective awareness of their mood, which in turn could have triggered particular processing strategies, and which may not be necessarily reflected in systematic modulations of ERPs. Participants' awareness of their mood may create several confounds. Participants may be describing their mood verbally to themselves, thus bringing explicit contextual linguistic information to bear into the integration process. They may also engage in mood repair (more likely in the case of sad mood) or mood maintenance (more likely in the case of happy mood). At best, such strategies would likely introduce noise into the study. In the worse case, however, they would induce modulation of ERP components only indirectly attributable to mood. The shift of attentional focus toward internal states has been shown to induce motivated processing and alter the effect of mood (e.g., Berkowitz et al., 2001; Martin, 1990). Making the source of mood salient has also been shown to completely eliminate its effect (e.g., Beukeboom & Semin, 2006; Schwarz & Clore, 1983). Finally, participants' subjective reports of their mood may be biased by experimental demands. To summarize, in our view, an implicit mood induction offers the most accurate and representative test of the actual effect of mood on cognition.

4.5. Conclusion

The interest for the impact of mood on language comprehension processes has developed mostly recently, and this is the first study to show that incidental mood can affect the N400 in discourse comprehension. In addition, although the number of studies that approach the investigation of language with auditory presentation is constantly increasing, this is the first study to evaluate the impact of mood on speech comprehension.

Recent ERP studies of language processing have shown that several types of contextual cues are jointly integrated by the language processing system, thus arguing for a broader construal of what serves as a context for discourse comprehension (Hagoort & van Berkum, 2007). These studies offer evidence against a two-stage model of comprehension, where the compositional meaning of a sentence is first constructed and then integrated with contextual factors (Cutler & Clifton, 1999). The present study contributes to strengthen a one-stage theoretical position (Hagoort, 2008; Hagoort & Van Berkum, 2007) by showing that the construal of context for discourse processing should be broadened even further, to include mood or emotional context that cannot be described by semantic or symbolic linguistic properties. Most important, because mood percolates into the information integration process and changes how discourse is understood, it must be included in a comprehensive theory of language understanding.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.bandl.2011.12.008.

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