Biological Psychology 88 (2011) 131–140

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Will the glass be half full or half empty? Brain potentials and emotional expectations

Eva M. Moreno[a,*], Carmelo Vázquez[b]

[a] Human Brain Mapping Unit, Instituto Pluridisciplinar, Universidad Complutense de Madrid, Paseo Juan XXIII, 1, 28040 Madrid, Spain
[b] School of Psychology, Universidad Complutense de Madrid, Campus de Somosaguas, 28223 Madrid, Spain

ARTICLE INFO

Article history:
Received 27 October 2010
Accepted 12 July 2011
Available online 26 July 2011

Keywords:
Event-related potentials (ERPs)
Language processing
N400
Post-N400 frontal positivity
Emotion regulation
Expectations
Optimism
Pessimism

ABSTRACT

Brainwave responses to words in context depend on semantic and world-knowledge expectations. Using the N400 component of event-related potentials as an index of word expectation, we explored brain responses to negatively and positively biased sentence frames randomly presented with their emotionally matched highly expected outcome or with violations that included switches to unexpected emotionally opposite outcomes or nonsense. Nonsense elicited large N400 responses regardless of the bias of the preceding sentence frame. Unexpected emotionally opposite outcomes elicited smaller than nonsense N400 responses and subsequent post-N400 frontal positivities, both unaffected by sentence frame bias. Over a midline-posterior scalp region, expected positive outcomes elicited larger N400 responses than negative ones, despite a high and matched word probability. Our study reveals that brains respond to unexpected emotional outcomes regardless of the direction of the emotional switch and hints at the possibility that the strength of positive and negative expectations may be adjusted before experiencing unexpected events.

Our species is endowed with both a tendency to expect positive outcomes for unknown future events, and a heightened sensitivity to negative outcomes (Cacioppo and Gardner, 1999; Vaish et al., 2008). People tend to have a stable, overall pessimistic or optimistic outlook in life (Scheier and Carver, 1985, 1987; Scheier et al., 1994). This appears to be crucial in determining affective responses, as *expectations* about what "might have been" play an important role in how people feel about what actually occurred. In fact, good and bad outcomes feel better or worse, respectively, when they are *unexpected* than when expected (Shepperd and McNulty, 2002). Interestingly, our tendency to make optimistic predictions about improbable bad outcomes (e.g. failing an exam) shift over time when feedback is anticipated in the near future, and when the outcome is uncontrollable (Carroll et al., 2006; Sweeny et al., 2006; Sweeny and Shepperd, 2007). Trying to avoid the disappointment of an unexpected bad outcome by anticipating troubles (Golub et al., 2009) or by using defensive pessimism strategies (Norem and Chang, 2002) may be adaptive. Nevertheless, the fact that most people exhibit positive illusions, including an unrealistic optimism about the future (Taylor and Brown, 1988), raises an intriguing question: can individuals avoid harboring good expectations even on the millisecond timescale of brainwave responses?

This question can be approached by analyzing the event-related potential (ERP), which allows examination of brain responses to expected and unexpected linguistic events with millisecond resolution. This technique has the additional advantage of not requiring overt responses or tasks beyond silently reading for comprehension. According to ERP studies, expectations in fact play an important role in language comprehension tasks. Thus, unexpected linguistic events such as a word that does not semantically fit in its sentence frame (e.g. the word city in the sentence *He shaved off his mustache and city*) elicit greater negativity at around 400 ms post-word onset than does a predictable, appropriate word such as beard (Kutas and Hillyard, 1980a, 1980b). The amplitude of the N400 component of the ERP is sensitive to the nature of the semantic relationship between any actual word and the word(s) that can be *expected* to complete the given sentence frame (Federmeier and Kutas, 1999). The *expected* completion of a sentence frame contains those words with the highest Cloze Probability (CP) in that context. The CP of a word in a given context refers to the percentage of individuals that choose it to complete the given sentence frame in a paper-and-pencil sentence completion task (Taylor, 1953). Brainwave analyses then reveal that N400 is smallest following words with high CP; intermediate or large following words that are, respectively, related or unrelated to the highest-CP completion; and largest following nonsense words (Kutas, 1987; Kutas and

* Corresponding author. Tel.: +34 91 394 32 61; fax: +34 91 394 32 64.
E-mail addresses: emmoreno@pluri.ucm.es (E.M. Moreno), cvazquez@psi.ucm.es (C. Vázquez).

0301-0511/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2011.07.003

Hillyard, 1984; Kutas et al., 1984). The fact that N400 depends on a word's semantic relationship to the expected completion indicates that individuals use knowledge stored in long-term memory to make online predictions about upcoming words (Federmeier and Kutas, 1999; Kutas and Federmeier, 2000). Other studies provide further evidence of an upcoming word prediction model (DeLong et al., 2005; Kutas et al., 2011; Van Berkum et al., 2005; Wicha et al., 2004). The N400 is also sensitive to violations of true facts from our world knowledge (Hagoort et al., 2004; Hald et al., 2007). For example, in the sentence '*The Dutch trains are white and very crowded*' the word '*white*' elicits an N400 response as it violates a known fact for Dutch speakers (i.e. Dutch trains are yellow). Interestingly, the N400 amplitude in response to a false statement is as large as the one in response to a nonsense word (e.g. '*sour*' in the previous example).

Although psycholinguistic research has mainly explored affectively neutral knowledge (Van Berkum et al., 2009), a large part of our world knowledge consists of experiences about what outcomes go with what types of emotional events. Indeed, messages devoid of emotional meaning may be the exception rather than the rule in everyday linguistic experience. One would be surprised to hear that after being left by her boyfriend, a woman reacted by flirting rather than by 'crying' or 'getting depressed'. There is, in some sense, a world knowledge that has to do with emotional rather than emotionally detached facts about the world. This knowledge reflects how likely we think it is that sad or happy events lead to sad or happy consequences. In fact, this orderly view of the emotional world is broken only under exceptional circumstances, such as severe traumatic experiences (Janoff-Bulman, 1989).

Making strong predictions about upcoming words in a sentence, however, may also carry a processing cost in situations in which those predictions prove false. An increased post-N400 frontal positivity (pN400FP) is observed between 500 and 900 ms over frontal electrode sites during the processing of unexpected word endings in highly constraining contexts (Federmeier et al., 2007). A similar but longer lasting pN400FP (500–1200 ms) has also recently been reported in response to strongly expected sentence continuations that go unfulfilled (DeLong et al., 2011). Therefore, while a small N400 response indicates the benefit of a fulfilled word expectation, the pN400FP effect has been proposed to reflect the consequences of processing a word that violates a prediction (Federmeier et al., 2007). In contrast to the long history of studies on N400 effects (Kutas and Federmeier, 2011) the pN400FP effect has only recently been regarded as a potential functionally independent ERP response linked to disconfirmation of strongly made predictions (DeLong et al., 2011).

The outcome of an incoming emotional message may not be under control in a passive reading task. Nevertheless, the brain may implement mechanisms to cope with negative and positive outcomes from incoming messages. People might anticipate happy and sad endings based on their emotional world knowledge, though these may also involve certain adaptive strategies. Adopting an optimistic or pessimistic strategy will alter expectations and therefore the ease or difficulty of semantic processing in a language comprehension task. We should be able to detect these alterations as changes in brainwave signatures (i.e. N400 and pN400FP) in response to expected and unexpected good and bad outcomes. Thus, tracing brainwaves in language comprehension tasks can provide information on how we prepare ourselves to process emotionally loaded information.

Studies of the processing of single emotional words have reported an early ERP (200–300 ms) arousal effect (pleasant and unpleasant versus neutral words) over left occipito-temporal electrodes (Kissler et al., 2007). The word's valence discrimination is reported to occur later, with pleasant word stimuli eliciting both a smaller N400 and a larger late positivity response than unpleasant word stimuli (Herbert et al., 2008). However, a recent picture-word priming study found N400 to be insensitive to emotion (Kissler and Koessler, 2011). ERP studies investigating the time course of processing single affective stimuli have given mixed results that depend on the type of stimuli (pictures, faces, words) and the type of task, e.g. reading for comprehension, memorization, lexical decision-making, and evaluation of emotional content (Fischler and Bradley, 2006; Kissler et al., 2006).

Only a few studies have examined ERP responses to emotional words in whole-sentence contexts. The early posterior negativity found in single word studies was not found, whereas a posterior late positivity discriminated between negative and neutral words (Bayer et al., 2010). Other studies examining N400 effects found that the amplitude of the N400 did not differ between negative and positive words (Holt et al., 2008), or that it was larger for negative words than for positive and neutral words (De Pascalis et al., 2009). In the latter study, the CP of target words, a strong determinant of N400 amplitude in sentence paradigms, was not reported. In the study by Holt et al. (2008), emotional and neutral words were all low-CP (2% on average) embedded in emotionally neutral contexts.

In tasks using emotional prosody (happy or sad intonation) to provide a context for subsequent processing of negative and positive words (e.g. 'success' or 'failure'), a larger N400 amplitude was found in response to words whose valence mismatched the prosody of the preceding sentence (Schirmer et al., 2002). A recent study also revealed that emotional prosodic expectancy violations elicit a right-lateralized, positive-going ERP effect, while combined semantic/prosodic expectancy violations elicit an early negativity ERP effect (Paulmann and Kotz, 2008).

Finally, some ERP studies have shown that an individual's current mood is crucial during information processing. Experimental mood inductions can make "happy" people more likely to accept some unexpected sentence endings (Federmeier et al., 2001) or make people in pessimistic moods more biased towards expectations of negative outcomes (Chung et al., 1996). Our study does not externally induce a mood; rather, it explores brainwave responses to the processing of fulfilled and unfulfilled positive and negative expectations during a sentence comprehension task. We aim to relate our findings to potential strategies that we may use to prepare ourselves for pleasant 'surprises' and 'setbacks'. Thus, our experimental design included negatively and positively biased sentence frames with a highly expected congruent ending, a nonsense ending, or an ending that is less expected and emotionally opposite to the expected one. In ERP studies, syntactically anomalous words presented at sentence-ending positions have been reported to elicit an increased negativity over anterior electrode sites between 300 and 500 ms relative to when the same anomalies appear in sentence-embedded positions (Osterhout, 1997). This effect has been considered to be driven by wrap-up processes that are potentially triggered at the end of sentences. However, words in context also tend to elicit smaller N400 responses as their predictability increases over the course of a sentence (Kutas and Federmeier, 2000). For the purposes of our study it is critical to induce a strong negative or positive expectation from the incoming message in order to be able to explore the response to its fulfilment or its violation. Thus, target words in our study appear at a point in the sentence in which ample semantic constraint has been built-up (i.e. sentence-final position), such that expectations are most likely entrenched.

We anticipate that N400 responses will be graded by expectancy, that is, by the CP of the target word ending; N400 amplitudes will be largest in response to nonsense endings, smaller in response to low-probabilility emotionally opposite endings, and smallest in response to highly probable emotionally congruent endings. Thus, fulfilled expectations will generate reduced

N400 amplitudes, whereas unfulfilled expectations will generate enhanced N400 responses followed by a pN400FP effect.

Despite the fact that expected negative and positive endings (fulfilled expectations) are bound to elicit the smallest N400 amplitudes due to their good emotionally semantic fit in context and their high CP value, brainwave differences between them may arise. We are biologically prompted to quickly and effectively identify and process aversive events (Baumeister et al., 2001; Vaish et al., 2008); indeed, a negativity bias has been reported in ERP studies using negatively and positively valenced pictures (Carretie et al., 2001; Ito and Cacioppo, 2000; Ito et al., 1998). In a sentence comprehension task, individuals may also be better at making accurate and fast online predictions about upcoming negative endings than upcoming positive ones, even if both endings have a similarly high CP value in a paper-and-pencil task. If we are more prone to accurately predict negative outcomes, they may elicit a smaller N400 than positive outcomes. At the same time, if we are able to avoid expectations of positive outcomes, they will elicit a larger N400 than negative ones. As mentioned earlier, a reduction in N400 amplitude in response to pleasant words has been suggested to index a natural bias towards positively valenced information in single-word processing paradigms (Herbert et al., 2008). However, since our experimental design forces individuals to process unfulfilled predictions by making possible both "happy" endings in negatively biased contexts and "sad" endings in positively biased ones, they may change the strength of their expectations under these unpredictable conditions, and they may make such adjustments differently, depending on whether the prediction is negatively or positively biased.

1. Methods

1.1. Participants

Twenty-four native Spanish speakers (21 female,[1] mean age = 21.3 years, range = 19–26 years) volunteered to participate in the study in exchange for course credit. The study protocol was approved by the Ethics Committee of the University, and participants gave written informed consent. Twenty-three participants reported being right-handed and one ambidextrous. The average handedness score (Oldfield, 1971) was +75.7 (range, +20 to +100). All participants reported normal vision and none had a history of neurological or psychiatric disorders.

1.2. Psychological assessment

Participants scored higher in positive affect state (mean = 34.2, SD = 5.9) than in negative affect state (mean = 15.2, SD = 5.9) ($t_{22} = 11.8$; $p = 0.001$), according to the Positive and Negative Affect Schedule (Watson et al., 1988). Their scores in the Beck Depression Inventory II (Beck et al., 1996) fell within the normal range (mean = 9.5, SD = 7.7) (Vázquez and Sanz, 1997). The Defensive Pessimism Questionnaire (DPQ) is a 12-item questionnaire that includes items such as "*I often start out expecting the worst, even though I will probably do OK*", and "*Considering what can go wrong helps me to prepare*" (Norem, 2001). Participants indicated the extent to which each item described them, from 1 (*not at all true of me*) to 7 (*very true of me*). Their mean score on the DPQ was 56.2 (SD = 9.5, range = 34-72).

1.3. Materials

In order to select CP-matched sentences for the ERP study, an initial set of experimental stimuli was created. It consisted of 420 sentence frames designed to bias strongly towards a positive or negative outcome. A norming procedure was conducted with 189 university students to determine the CP values of plausible word endings. Students completed one of six lists (28–35 participants per list), each of which comprised 70 sentence frames. They were asked to read each one and write down the word they would generally expect to find completing the sentence fragment (Response 1, R1). Following Federmeier's extension procedure, students were also instructed to give two additional plausible completions (R2 and R3) (Federmeier et al., 2007).

A final set of 210 sentence frames was then selected for inclusion in the ERP experiment. Positively biased (105) and negatively biased (105) sentences were selected such that their endings were equally highly expected words. The mean CP values for the words as an R1 did not differ (73% on average; $t_{208} = 0.69$; $p = 0.49$) (Table 1). During the experiment we randomly presented each sentence with its highly expected ending (33.3% of the time, "expected ending" condition), with a nonsense ending (zero CP value, "nonsense" condition), or with a word that reversed the sentence's intended emotional valence ("emotionally opposite" condition). Table 2 shows examples of sentences and their endings. Emotionally opposite word endings were, when possible, drawn from our subjects' R2 or R3 responses and never had more than a 10% CP as an R1 (average CP of 0.8% as an R1). Three experimental lists were constructed such that each ending was assigned to a list in order to avoid sentence repetition effects; the frequency of use (Sebastián-Gallés et al., 2000), length, and CP of ending words were matched within and across lists (Table 3). Each list was randomly assigned to 8 participants per list. Sentences were randomized within each list such that there were no more than 5 consecutive positively or negatively biased sentences.

1.4. Experimental procedure

Participants were fitted with encephalogram (EEG) electrodes and they filled out handedness, vision and health questionnaires. They were seated approximately 100 cm in front of a 17 in. computer monitor. The session began with a short set of practice sentences to acclimate the participants to the reading task. Sentences were always presented one word at a time, in the center of the screen in black, lower-case Arial font (maximum letter height, 1.27 cm) on a white background. Each word was presented for 200 ms, with the exception of the final word, which was presented for 500 ms. The interstimulus interval was 300 ms. A "Press to continue" message in blue font followed each sentence. Participants were asked to blink if needed and then press a button to initiate the next sentence. They were also instructed to read each sentence for comprehension, since they would be asked questions about them at the end of the recording session. Lists were divided into 5 blocks of 42 sentences each. The participants proceeded from one block to the next at their own pace.

At the end of the recording session, participants completed a 42-sentence recognition test; six of these sentences had never been seen before (lure sentences), and six came from each of the positively or negatively biased sentences with the expected, emotionally opposite, or nonsense endings described above. All sentences were presented with the actual ending that participants had already seen, as well as two other endings that they had not seen before and that were drawn from the other experimental lists. Their task was to mark from among the three provided endings the one that they had seen during the reading task. Participants were generally accurate in recognizing previously seen endings: there were 73.5% hits, 24.5% false alarms, and 1.9% omissions, including the results with the lure sentences.[2] The percentage of hits was subjected to repeated-measures ANOVA with two levels of Emotional frame (positively or negatively biased) and three levels of Expectancy (expected, emotionally opposite, nonsense). A main effect of Emotional Frame was not present [$F(1, 23) = 0.026$; $p = 0.873$] indicating that participants accurately recognized endings of negatively and positively biased sentences to the same extent (71.7% and 71.3%, respectively). There was a main effect of Expectancy [$F(2, 46) = 3.865$; $p = 0.032$]. Post-hoc Bonferroni-corrected t tests revealed that there was only a marginally significant difference ($p = 0.06$) between hits in sentences that had been presented with a nonsense ending (64.9%) and hits in sentences with a highly expected word ending (78.5%).

After the recognition test, participants completed a set of psychological measures, which included the Defensive Pessimism Questionnaire (DPQ), the Positive and Negative Affect Schedule (PANAS), the Beck Depression Inventory II (BDI-II), the Patient Health Questionnaire Depression Module (PHQ-9) and the Life Orientation Test Revised (LOT-R). Only the data from the DPQ were used in the analysis presented here. Scores on the PANAS and the BDI-II tests are reported in the Psychological Assessment section to provide some general features of our participant sample.

1.5. EEG recording and analyses

EEGs were recorded from 31 tin electrodes mounted in an electrode cap (Electro-Cap International, Eaton, Ohio, USA). Electrode impedances were kept below 5 kΩ. Electrodes were referenced online to the left mastoid, amplified with Brain Amps amplifiers (Brain Products, Munich, Germany) at a sampling rate of 250 Hz with a bandpass of 0.01–40 Hz, and re-referenced off-line to the mastoid average.[3] Bipolar horizontal and vertical electrooculograms (EOGs) were recorded for artifact rejection and correction purposes, using the method of Gratton et al. (1983). Data were processed using BrainVision Analyzer software (Brain Products, Munich). After visual inspection of individual data files, the following artifact threshold criteria were set: maximal allowed voltage step, 50 μV; minimal and maximal allowed amplitude, ±100 μV; lowest allowed activity (max–min), 5 μV for a 1500 ms inter-

[1] A replication of the analyses, restricted to the subset of 21 females, did not significantly alter the direction of overall results.

[2] One participant was excluded from further ERP analysis as she correctly recognized only 47.6% of endings.

[3] Electrode sites were Fp1/z/2, F7/3/z/4/8, FT7/8, FC3/z/4, T7/8, C3/z/4, TP7/8, CP3/z/4, P7/3/z/4/8, O1/z/2.

Table 1
Cloze probabilities, frequency of use, and number of letters of expected, emotionally opposite, and nonsense word endings for negatively and positively biased sentence frames.

Type of word ending		Sentence frame type					
		Negatively biased ($n = 105$)			Positively biased ($n = 105$)		
		Mean	Range	SD	Mean	Range	SD
No. of subjects in norming study (per sentence)		31	27–33	2.2	32	28–33	2
Cloze probability[a]	% Expected (R1)	73.6	50–100	14.1	72.2	50–100	14.2
	% Expected (R2)	10.8	0–31	6.7	10.8	0–38	7.3
	% Expected (R3)	3.5	0–18	3.4	4.3	0–14	3.6
	% Expected (R1–R2–R3)	87.1	62–100	9.8	86.7	61–100	10.4
	% Emotionally opposite (R1)	0.7	0–10	1.9	0.9	0–10	2
	% Emotionally opposite (R2)	3.5	0–39	5.9	3.5	0–30	5.1
	% Emotionally opposite (R3)	3.2	0–18	4	3.2	0–27	4.1
	% Emotionally opposite (R1–R2–R3)	7.4	0–48	9.1	7.6	0–48	8.2
Frequency of use	Expected	181	0–1535	280	215	0–3744	493
	Emotionally opposite	205	0–3744	517	195	1–3249	459
	Nonsense	205	0–1923	358	206	0–2634	398
No. of letters	Expected	6.7	3–10	1.6	6.9	3–11	1.9
	Emotionally opposite	7.2	3–12	2.1	6.9	3–12	2
	Nonsense	7	3–11	1.8	6.9	3–11	1.7

[a] Cloze probability values are reported separately based on whether participants in the norming study gave them as an R1, R2, or R3 response, or as any of them (R1–R2–R3). Nonsense completions were never reported by our participants and therefore always had a CP value of zero.

val length. Once any threshold was met in the continuous EEG file, data recorded at that point were marked and discarded, together with data recorded during the 200 ms before and after the detected artifact. This was done to avoid including any residual artifacts in subsequent computations of ERP averages. EEG raw data from all subjects were scanned and marked using the same artifact rejection criteria. As a result, 12% of trials were discarded and an average of 30.8 trials remained per experimental condition.

A Butterworth zero phase filter was applied to the EEG data (low cutoff at 0.1 Hz, time constant = 1.6 s, 24 dB/oct; high cutoff at 20 Hz, 24 dB/oct). The continuous EEG was segmented into 1000-ms epochs starting 100 ms before the onset of the target word ending. Artifact-free average waveforms were calculated for each word ending (expected, nonsense, emotionally opposite) in positively and negatively biased sentence frames after subtraction of the pre-stimulus baseline.

2. Results

2.1. N400 effects

In negatively and positively biased sentences, nonsense endings elicited the largest N400 responses, highly expected endings the smallest, and emotionally opposite endings intermediate responses (Fig. 1A). A repeated-measures ANOVA was carried out with two levels of Emotional Frame (negatively and positively biased), three levels of Expectation (expected, emotionally opposite, nonsense) and ten levels of scalp Region of Interest (ROIs).[4] The analysis revealed main effects of both Expectation [$F(2,46) = 54.751$; $p = 0.001$] and ROI [$F(9,207) = 8.201$; $p = 0.001$], as well as an interaction of Expectation by ROI [$F(18,414) = 21.761$; $p = 0.001$].[5] Paired comparisons using Bonferroni-corrected t-tests confirmed that nonsense endings elicited larger negative-going potentials than emotionally opposite endings, and that both of these unexpected endings elicited larger negative-going potentials than highly expected endings [means: nonsense (0.3 μV) < emotionally opposite (1.7 μV) < highly expected (3.1 μV); all $ps < 0.001$). Follow-up ANOVAS on each ROI revealed this to be the pattern at all regions except for the left and right fronto-lateral ROIs, where there was only an incongruity effect, i.e. nonsense endings differed from emotionally opposite and highly expected endings, but the latter two did not differ from each other.

Of critical interest for the present study was whether CP-matched word endings, would elicit N400 responses of different amplitude as a function of the emotional bias of the preceding sentence frame. Thus, ANOVAs were also conducted for each expectation condition. Nonsense and emotionally opposite experimental conditions showed no significant effects of the type of Emotional Frame at any scalp ROI. Thus, nonsense endings elicited a similarly large N400 response regardless of whether they were preceded by positively or negatively biased frames (Fig. 1Bb). Similarly, emotionally opposite endings elicited medium-sized N400 responses regardless of emotional frame at all scalp ROIs (Fig. 1Bc). In contrast, the ANOVA on the response to highly expected endings revealed an Emotional Frame effect in the midline posterior region (ROI # 8), which included electrodes Cz, CPz, and Pz [$F(1,23) = 4.374$, $p = 0.048$]. Highly expected *positive* endings elicited a larger negative-going potential than highly expected *negative* endings (4.2 μV *vs.* 5.2 μV, respectively), even though they were both embedded in emotionally matched sentence frames. This effect was localized to that ROI and was not statistically significant at any other scalp region. Only the left posterior-medial region (ROI # 7) approached significance ($p = 0.07$). Thus, despite sharing a high CP value and a sentence frame providing an emotionally matching contextual constraint, the positive expected outcomes elicited a slightly larger N400 response than did the negative expected ones in the midline posterior scalp region (Fig. 1Ba).

2.2. Post-N400 effects

Between 600 and 900 ms, a larger frontal positivity was elicited by emotionally opposite endings than by expected and nonsense endings (Fig. 1A). A repeated-measures ANOVA on a frontal ROI[6] revealed main effects of both Expectation [$F(2,46) = 5.120$;

[4] ROIs location and electrodes included: (1) left fronto-lateral (Fp1, F7, FT7); (2) left fronto-medial (F3, FC3, C3); (3) midline frontal (Fpz, Fz, FCz); (4) right fronto-medial (F4, FC4, C4); (5) right fronto-lateral (Fp2, F8, FT8); (6) left posterior-lateral (T7, TP7, P7); (7) left posterior-medial (CP3, P3, O1); (8) midline posterior (Cz, CPz, Pz); (9) right posterior-medial (CP4, P4, O2) and (10) right posterior lateral (T8, TP8, P8).

[5] Analyses were restricted to the 250–550 ms window to avoid overlap with prior P2 deflections and later post-N400 frontal positivity (pN400FP). The Greenhouse–Geisser correction was applied to this and all subsequent analyses in all F tests with more than one degree of freedom in the numerator.

[6] The frontal ROI included electrodes F3, Fz, F4, FC3, FCz, and FC4.

Table 2
Examples of sentence frames and target word endings in the event-related potentials (ERP) experiment.

Sentence frame[a]	Ending type				
	Expected	CP as R1[b] (%)	Emotionally opposite	CP as R1, R2, or R3[b] (%)	Nonsense
Negatively biased					
En el borde del acantilado, alguien vino por detrás y le. . . At the edge of the cliff, someone came from behind and [him]. . .	. . .empujó. . . .*pushed.*	78.8	. . .rescató. . . .*rescued.*	6.1	. . .inventó. . . .*invented.*
Aquello era tan repugnante que me hizo. . . That was so disgusting that it made me. . .	. . .vomitar. . . .*throw up.*	78.8	. . .reír. . . .*laugh.*	9.1	. . .brotar. . . .*sprout.*
Abrí el cajón dónde normalmente guardo el dinero y estaba. . . I opened up the drawer where I usually keep the money and it was. . .	. . .vacío. . . .*empty.*	72.7	. . .allí. . . .*there.*	24.2	. . .hablando. . . .*talking.*
Mi jefe estaba descontento conmigo y un buen día me. . . My boss was unhappy with me and one fine day [me]. . .	. . .despidió. . . .*fired.*	69.7	. . .felicitó. . . .*complimented.*	12.1	. . .abrochó. . . .*buttoned up.*
Siempre que tienes una emergencia la línea está. . . Whenever you have an emergency the line is. . .	. . .ocupada. . . .*busy.*	60.6	. . .disponible. . . .*available.*	6.1	. . .chapoteando. . . .*splashing.*
Un paciente de psiquiatría abrió una ventana y se. . . A psychiatric patient opened up a window and [himself]. . .	. . .tiró. . . .*threw out.*	51.5	. . .asomó. . . .*leant out.*	18.2	. . .parpadeó. . . .*blinked.*
Positively biased					
Después de 10 años de matrimonio, todavía seguían estando muy. . . After 10 years of marriage, they still remained very much. . .	. . .enamorados. . . .*in love.*	72.7	. . .mal. . . .*badly.*	3	. . .soleados. . . .*sunny.*
El público se puso inmediatamente en pie y le. . . The audience immediately stood up and [him]. . .	. . .aplaudió. . . .*applauded.*	75	. . .gritó. . . .*shouted at.*	17.9	. . .podó. . . .*pruned.*
Esos detalles conmigo demostraban lo mucho que me. . . Those little thoughtful details revealed how much [he/she] [me]. . .	. . .quería. . . .*loved.*	69.7	. . .envidiaba. . . .*envied.*	6.1	. . .resumía. . . .*summarized.*
Cuando le vio regresar sano y salvo se. . . When [he/she] saw him coming back safe and sound [he/she]. . .	. . .alegró. . . .*[was] happy.*	63.6	. . .enfadó. . . .*[got] angry.*	12.1	. . .regó. . . .*[got] watered.*
Aquella brisa marina en el rostro era muy. . . That sea breeze on [my/his/her/our/their] face was very. . .	. . .agradable. . . .*nice.*	57.6	. . .molesta. . . .*annoying.*	9.1	. . .social. . . .*social.*
Comprando las cosas para la fiesta también nos. . . While buying things for the party we also. . .	. . .divertimos. . . .*[had] fun.*	53.1	. . .perdimos. . . .*[got] lost.*	18.8	. . .decoramos. . . .*[got] decorated.*

[a] An approximate translation into English is offered in italics. Personal pronouns precede verbs in Spanish. Thus, in our translation the pronoun is inserted in the sentence frame prior to the ending target word to indicate that it was provided in Spanish before the verb came up at the screen.
[b] Based on our norming study (see Section 1). For expected endings we report their CP as a first response (R1), since it indicates the strength of the expectation. For emotionally opposite endings, we report their Cloze probability as either R1, R2 or R3, since this indicates the likelihood that the word will enter the reader's mind, even if it is not his or her first choice. Nonsense endings were never reported by our participants and therefore always had a CP value of zero.

$p = 0.01$] and Electrode [$F(5, 115) = 6.207$; $p = 0.001$], as well as the interactions Expectation by Electrode [$F(10, 230) = 4.319$; $p = 0.002$] and Emotion by Electrode [$F(5, 115) = 3.893$; $p = 0.013$]. Paired-sample two-tailed *t*-tests on amplitude measures in this ROI revealed that the response to emotionally opposite endings differed in size from that of expected endings in both negatively ($t_{23} = -3.192$; $p = 0.004$) and positively biased frames ($t_{23} = -2.140$; $p = 0.04$). The effect appeared to be slightly larger for negatively than for positively biased sentences, but these amplitude differences did not reach statistical significance ($t_{23} = -1.641$; $p = 0.11$). Moreover, nonsense endings did not differ from expected endings in pN400FP amplitude (negatively biased sentences, $t_{23} = -0.403$, $p = 0.69$; positively biased sentences, $t_{23} = -0.728$, $p = 0.44$).

Table 3
Cloze probability, frequency of use, and number of letters in target word endings arranged by sentence frame type within each list.

List	Ending type	Sentence bias[a]	Cloze probability of target word endings in their sentence frame				Word frequency	No. of letters
			% as R1	% as R2	% as R3	% as R1–2–3		
1	Expected	N	70.1	12.5	3.5	86.0	117.7	7.1
		P	69.5	10.0	4.2	83.3	110.2	7.5
	Emotionally opposite	N	0.6	2.1	2.7	5.4	268.0	7.7
		P	0.6	3.1	3.3	6.9	309.8	6.6
	Nonsense	N	0	0	0	0	233.3	6.7
		P	0	0	0	0	184.5	6.7
2	Expected	N	74.2	10.2	3.3	87.1	165.5	6.6
		P	71.6	13.5	4.9	88.4	220.5	6.6
	Emotionally opposite	N	0.7	3.1	2.5	6.4	98.4	7.2
		P	0.6	3.9	3.0	7.6	136.1	7.3
	Nonsense	N	0	0	0	0	187.1	7.3
		P	0	0	0	0	321.9	7.1
3	Expected	N	76.5	9.6	3.8	88.2	259.7	6.5
		P	75.7	9.1	3.8	88.5	313.8	6.9
	Emotionally opposite	N	0.9	5.4	4.3	10.5	248.0	6.7
		P	1.5	3.4	3.3	8.3	140.4	7.0
	Nonsense	N	0	0	0	0	194.6	6.9
		P	0	0	0	0	112.5	6.8

[a] N, negatively biased; P, positively biased.

2.3. Defensive pessimism and ERP effects

An inter-subject variable, high versus low score on the DPQ, was added to the repeated-measures ANOVA analyses described above. The participants' median-split score was 55 (range = 34–72), with 10 participants' scoring 56–72 (high defensive pessimist group, HDP), and 11 participants scoring 34–53 (low defensive pessimist group, LDP).[7]

The HDP group showed a similar response to all ending types until approximately 200 ms (Fig. 2A). Then, a three-way split occurred in the N400 region for each type of ending. The size of the N400 ERP component followed the trend nonsense > emotionally opposite > expected, as described earlier with regard to the entire sample of 24 participants. In contrast, the LDP group seemed to show early brainwave modulations before 200 ms. However, earlier deflections around the P2 peak may be driven by a developing N400 effect. Thus, we continued to focus our analyses on the amplitude measured within the N400 time-window.

Between 200 and 800 ms, the HDP group showed a larger and sustained negative-going voltage in response to expected endings that was larger than that of the LDP group (Fig. 2Ba). ANOVAs restricted to the N400 time-window of analysis (250–550 ms) over a centro-parietal electrode region[8] revealed a main effect of DP [$F(1, 19)$; $p = 0.039$]. Unpaired-sample two-tailed t-tests revealed that amplitude measures significantly differed between groups both for positively biased expected endings ($t_{19} = 2.958$; $p = 0.008$) and negatively biased ones ($t_{19} = 2.586$; $p = 0.018$). These results may suggest that the HDP group generally seemed to avoid holding expectations. Pearson r coefficient analyses showed significant correlations between the DP score and the voltage measured between 250 and 550 ms in response to highly expected word outcomes at specific centroparietal electrodes (i.e. $r = -.477$, $p = 0.029$ at CP4; $r = -.461$, $p = 0.035$ at Pz). Higher scores on the DP questionnaire predicted more negative-going brainwave responses (i.e. smaller positive voltage). In the same time-window, the groups did not differ in the response to nonsense or emotionally opposite endings (Fig. 2Bb and 2Bc). Only the N400 response to "happy" endings that were preceded by negatively biased sentence frames appeared to be larger in the HDP than the LDP group (Fig. 2Bc). However, this effect was not statistically significant ($p = 0.09$).

2.4. Summary of results

N400 amplitudes were graded by Expectation (Expected < Emotionally Opposite < Nonsense) and showed no main effects of Emotional frame. Between 250 and 550 ms, a similar triphasic pattern of ERP deflections was observed for the two types of emotionally biased sentences. Emotional frame did, however, have an influence on N400 size when the response to highly expected word outcomes was examined in isolation. Positive expected outcomes elicited larger N400 amplitudes than did negative ones in a midline posterior scalp region, suggesting that the semantic integration/prediction of word endings was easier in the case of negative expectations than positive ones or that the positive predictions were easier to withhold. Subsequent to the N400 effect (between 600 and 900 ms), positivity over frontal electrode sites (pN400FP) was larger in response to emotionally opposite endings than to expected and nonsense ones, indicating that unfulfilled emotional expectations were more difficult to process than fulfilled or nonsense ones, regardless of the preceding emotional frame. Further analyses seem to indicate that individual differences in personal strategies (i.e. defensive pessimism) may be linked to specific patterns of brainwave responses. However, these results should only be considered exploratory, since the sample size within each group was quite limited.

3. Discussion

In line with previous ERP studies, N400 responses were greatest in response to nonsense endings (e.g. spending restless nights '*being born*' after being left by a boyfriend), intermediate in response to less likely but still plausible endings ('*flirting*'), and lowest in response to highly expected CP endings ('*crying*'). In our study the word '*flirting*', in addition to being a low-CP ending (0.8% as an R1), also critically violated the expectation of an emotional outcome ('*crying*'). Thus, violations of emotionally loaded expectations gave rise to an N400 effect: i.e. N400 was larger for endings emotionally opposite to the highly expected emotional outcome. This effect

[7] Three participants scoring 55 were left out for the purposes of the present analysis.
[8] This region included electrodes FCz, C3, Cz, C4, CPz and Pz.

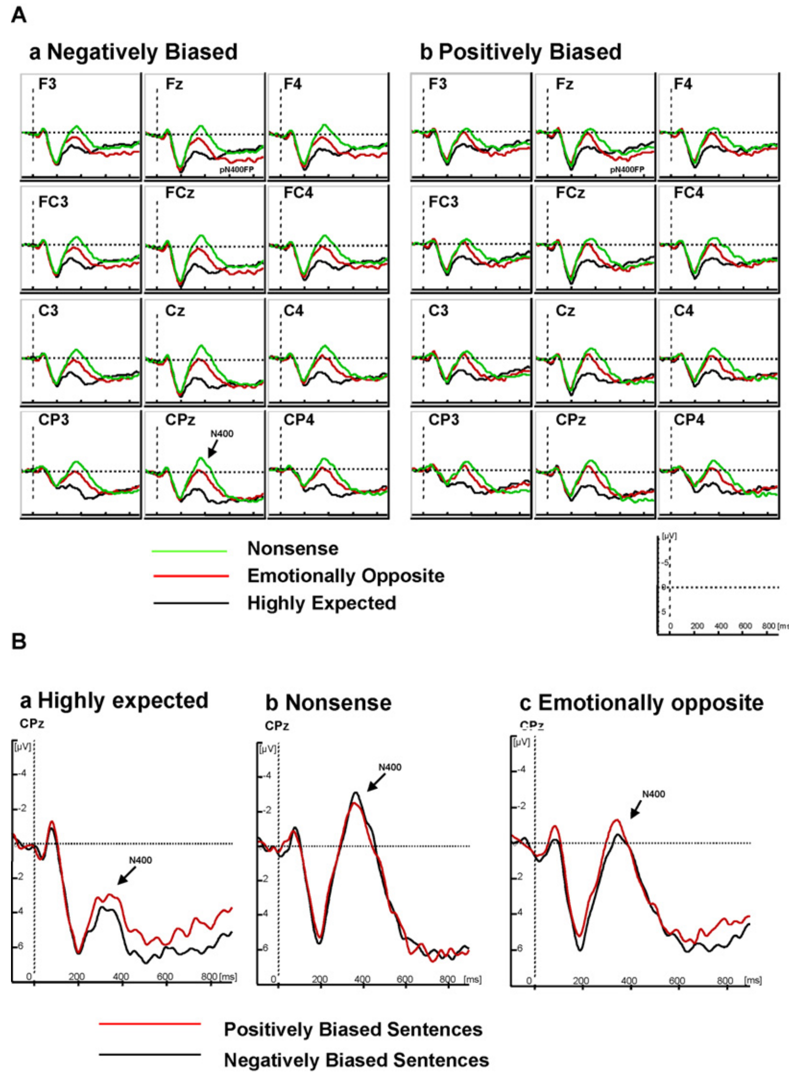

Fig. 1. (A) Brain activity of participants ($N = 24$) at 12 electrode channels in response to expected, emotionally opposite, and nonsense endings when they were embedded in negatively (a) or positively (b) biased sentence frames. The N400 component is indicated with an arrow and labelled at a centroparietal midline electrode (CPz). The post-N400 frontal positivity (pN400FP) is labelled at a frontal midline electrode (Fz). In Figs. 1 and 2, voltage (in μV) is displayed with negative voltage above the x-axis, and time (in ms) is shown relative to the onset of the critical ending word at time 0. A three-way split depending on the type of ending can be observed in the amplitude of the N400 response. The N400 was smallest for expected endings (black), slightly larger for emotionally opposite endings (red) and largest for nonsense endings (green). In contrast, the pN400FP was larger for emotionally opposite endings (red) and similar for expected (black) and nonsense (green) endings. (B) Brain activity at the CPz electrode is shown in response to highly expected (a), nonsense (b) and emotionally opposite (c) endings as a function of whether they were embedded in negatively (black) or positively (red) biased sentence frames. The N400 was similar for nonsense (b) and emotionally opposite (c) endings regardless of emotional frame. In contrast, the amplitude of the N400 ERP component was larger and more sustained for highly expected positive outcomes than for highly expected negative ones (a).

may be due solely to the low CP of the word or to both the low CP and the fact that an emotional switch was concurrently taking place when that target word appeared. Interestingly, the size of the N400 response to endings that violated expectations either emotionally or semantically was larger for the nonsense than for the emotional opposites, but it was unaffected by whether the context biased our participants towards a negative or positive expectation. According to our N400 results, less plausible emotionally opposite endings were always easier to integrate or were more predictable in their context than nonsense endings, regardless of whether participants had strongly been biased towards expecting a "good" or "bad" outcome.

Surprisingly, although highly expected outcomes elicited the smallest N400 responses, as expected based on the N400 literature, emotional frame modulated responses to this kind of outcome, but not responses to the other outcomes. Thus, although positive and negative expected outcomes had a similarly high paper-and-pencil CP value as well as a preceding emotionally matched frame, the positive outcomes elicited a larger negative-going voltage than negative ones, as measured at a midline posterior region in the N400 time-window. We regard this effect as preliminary due to its limited scalp location and its weak statistical significance. Nonetheless, the integrative and the predictive views of the N400 component may suggest a different interpretation of this result. According to the integration view, N400 amplitude variation would indicate our participants were forced to devote fewer resources to integrating the negative words than the positive ones into their context, even though both were highly expected based on paper-and-pencil offline measures. According to the prediction view, readers were better at using negative contexts than positive ones to generate expectations for an outcome word. Our data do not allow us to determine whether people are better at successfully integrating/predicting negative outcomes than positive ones, or they are reluctant to make predictions of "happy" outcomes, or both. Future studies should seek to discern between these alternative interpretations.

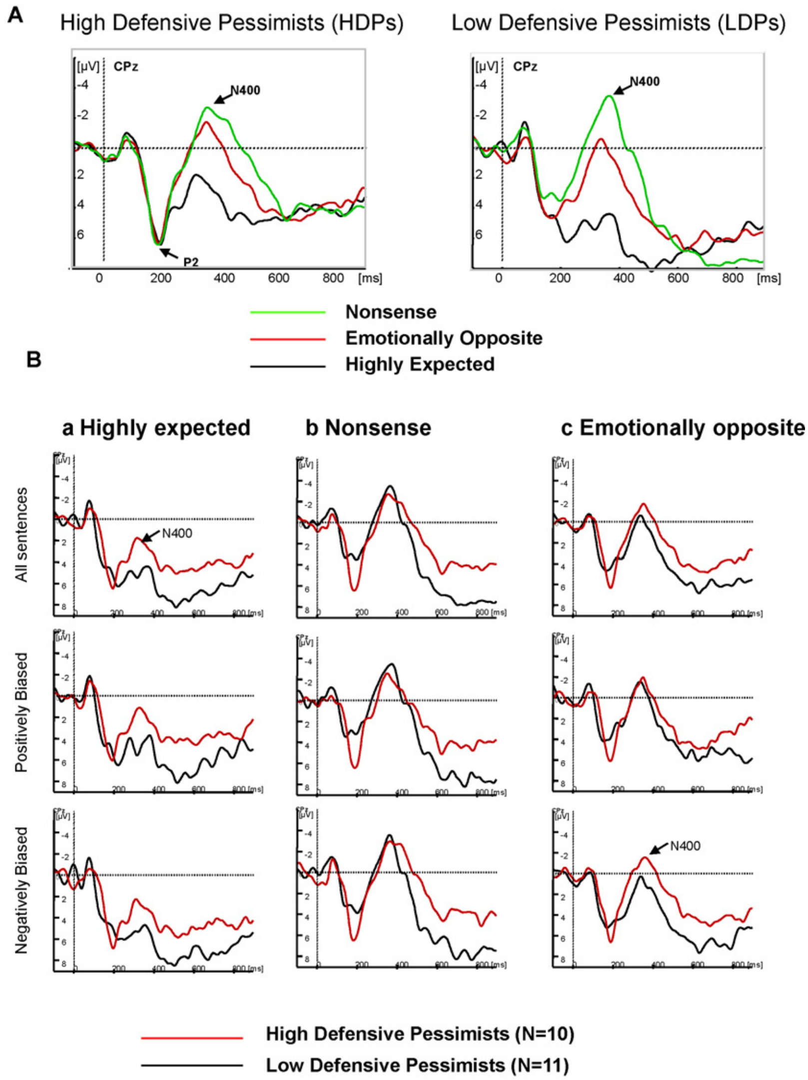

Fig. 2. (A) Brainwave responses at a centro-parietal midline electrode channel (CPz) are shown for participants scoring high (HDP, $N = 10$, left) and low (LDP, $N = 11$, right) in the Defensive Pessimism Questionnaire. When processing each type of ending, the LDP group (right) began to show brainwave differences around the P2 peak (marked as "P2"), earlier than the HPD group (left). Subsequently, N400 responses in the two groups showed a similar triphasic pattern, although their relative amplitudes differed under some conditions, as shown in (B). (B) Brain responses of HDP and LDP participants are shown for highly expected (a), nonsense (b), and emotionally opposite (c) endings. The top row shows the combined ERP activity across all sentence types. The second row shows responses in negatively biased sentences; the third row, in positively biased sentences. For expected endings (a), the N400 response of HDPs (red) was always larger than that of LDPs (black), regardless of whether the sentence was biased towards a positive or a negative outcome (second and third rows). In contrast, the N400 response did not differ overall between the two groups in response to nonsense (b) or to emotionally opposite endings (c). N400 amplitude was slightly lower for LDPs than for HPDs for 'happy' endings in negatively biased sentences (indicated in the third column, third row), but this difference was only marginally significant.

In our experimental design, the emotionality of the target word and the emotionality of the sentence frame always agreed for highly expected endings and always disagreed for emotionally opposite endings. However, the CP value of all target endings was matched across emotionality in both high and low CP conditions. Differences in the relative sizes of N400 and pN400FP responses may be attributed to the emotionality of the frame in which high and low CP endings occurred. Nonetheless, negative and positive emotional frames may also behave as better primers of their respective negative or positive endings, and this alternative low-level account of N400 effects must also be considered (see Kutas et al., 2011; Van Berkum et al., 2005 on the integrative/predictive views of N400 effects).

At present, only a few studies have used a whole-sentence comprehension paradigm to explore the mechanisms underlying the processing of emotionally evocative language (De Pascalis et al., 2009; Holt et al., 2008; Bayer et al., 2010). Results from the two of these studies in which N400 effects were explored, contrast with the ones obtained in the present work. Those studies found that N400 was modulated by arousal but not by emotional valence (Holt et al., 2008); or that it was larger for negative than for positive and neutral words (De Pascalis et al., 2009). These contrasting results may arise from significant methodological differences across studies. In the study by De Pascalis et al. (2009), word CP was not accounted for. Thus, N400 effects may have arisen due to a lower word CP for negative relative to positive/neutral words. In the study by Holt et al. (2008), word CP was low for sentence-embedded targets (2% on average). Critically, and in contrast to our study, their contexts were emotionally neutral, which may have led to an N400 effect for any emotional target, whether positive or negative, but not for neutral targets. Moreover, their offline-measured word CP was slightly larger for positive (3.5%) than negative (1.4%) and neutral targets (1.1%). This behavioral result fits with theoretical models that postulate that, by default, people tend to be optimistic about upcoming events (Taylor and Brown, 1988), as well as with single-word ERP studies reporting smaller N400 responses to positive than neutral words (Herbert et al., 2008). Our ERP study ensured a high and matched CP value across negative and positive sentence frames by performing an initial word CP norming study that aimed to select matched sentences for the brainwave study. In our ERP scenario, in which positive and negative expectations were equally strongly biased but were randomly violated, we found a local increase in N400 in response to highly expected positive word endings compared to highly expected negative ones. We speculate that participants in our study were particularly reluctant to make predictions of "happy" outcomes under such unpredictable conditions. According to social psychology studies, positive predictions tend to shift away from being *positive* as feedback information is soon becoming available and when the outcome is uncontrollable (Carroll et al., 2006).

Our group analyses also preliminarily suggest that *defensive pessimism* strategies might induce people to avoid holding expectations in emotional contexts. However, we did not obtain separate estimates of word ending CPs for high versus low defensive pessimists. Future studies are needed to explore more thoroughly individual differences in ERP response patterns under evocative language processing tasks. In the current study individual affect ratings of target words and their preceding emotional frames was not measured. Sentence frames were designed simply to bias towards a good or a bad outcome (e.g. dying, falling from heights, laughing, having fun). In future studies emotionality rating levels might reveal better defined ERP effects and also clarify potential individual differences in brainwave responses.

As previous ERP studies indicate, pN400FP effects index the cost associated with the processing of an unfulfilled expectation in a highly constrained context (DeLong et al., 2011; Federmeier et al., 2007). Our results show that, indeed, processing an emotionally unexpected word in a highly constrained context does incur a cost. However, since the pN400FP effect may reflect the need to inhibit or revise a strong expectation (Federmeier, 2007), our results suggest that such revision may have been unnecessary for sentences in which an emotionally loaded expectation did not make sense at all (i.e. nonsense condition). Moreover, a larger pN400FP in response to emotionally opposite outcomes under the influence of negative expectations than under the influence of positive expectations may indicate that negative predictions were more strongly entrenched than positive ones. Our results point in that direction, but we failed to find statistically significant amplitude differences over the frontal scalp region. Perhaps the proposed partial temporal overlap between frontal pN400FP and posterior N400 effects (DeLong et al., 2011) may be present in our data.

In conclusion, in time-constrained scenarios in which biased negative and positive expectations may or may not be fulfilled quickly at random, brainwave responses reveal no difference in N400 amplitude depending on whether the emotional violation represents an 'emotional setback' (i.e. worse than expected) or a 'pleasant surprise' (i.e. better than expected). These expectations do, however, incur a processing cost, as indexed by the subsequent pN400FP effect. Again, however, the direction of the emotional switch does not seem to make a difference. Nonsense endings pose a difficulty for integration/prediction, as indexed by an enhanced N400 response, but the pN400FP that indexes the need of a revision of a strongly held prediction was not present. Finally, an interesting result was obtained when ERPs to highly expected outcomes was explored. In this condition, negative and positive word endings shared an equally high CP value as well as an emotionally matched preceding sentence frame. The N400 amplitude under these conditions was consequently reduced relative to the other conditions. However, results obtained at a focal midline posterior scalp region suggest that the negative and the positive highly expected outcomes might have been processed differently. In light of our results, we can only speculate that relevant phenomena described in the social psychology literature (e.g. the proximity of real feedback and lack of control over the outcome) may play a critical role in our online language comprehension task. Since bad outcomes feel worse when unexpected than when expected, nature may have endowed us with the ability to make accurate predictions of negative outcomes to avoid the 'extra' pain when such an outcome is unexpected. In addition, since good outcomes feel better when unexpected than when expected, we seem to be good at avoiding harboring positive expectations in order to maximize the good feeling that results when they end up coming true. Recent studies on hedonic adaptation (Diener et al., 2006) suggest that people adapt quickly to the presence of positive events because they tend to become "unsurprising" (Koo et al., 2008). In our study, the larger N400s for highly expected positive outcomes might indicate that our participants still managed to find those outcomes 'surprising', at least more so than the negative ones.

Our study illustrates how brainwave measurements obtained during a language comprehension task might provide information about how individuals cope with emotionally loaded incoming information. Our results provide preliminary evidence that in time-constrained affective scenarios, humans may selectively adjust the strength of their positive and negative expectations before a verbal input comes in.

Acknowledgements

This original research has not been published elsewhere and was supported by Spanish Ministry of Science and Innovation grant PSI2008-04961 to E.M.M. and grants PSI2008-02889-E and SEJ-PSI2009-13922 to C.V. We thank Carmen Gómez-Nuñez, María Provencio, and Claudia Del Pozo-Moreno for their help during data collection, Armando Chapin Rodríguez for manuscript editing, and all the participants in our study for their cooperation.

References

Baumeister, R.F., Bratslavsky, E., Finkenauer, C., Vohs, K.D., 2001. Bad is stronger than good. Review of General Psychology 5 (4), 323–370.

Bayer, M., Sommer, W., Schacht, A., 2010. Reading emotional words within sentences: the impact of arousal and valence on event-related potentials. International Journal of Psychophysiology 78 (3), 299–307.

Beck, A.T., Steer, R.A., Brown, G.K., 1996. BDI-II: Beck Depression Inventory: Manual, 2nd ed. Psychological Corp., Harcourt Brace, San Antonio.

Cacioppo, J.T., Gardner, W.L., 1999. Emotion. Annual Review of Psychology 50, 191–214.

Carretie, L., Mercado, F., Tapia, M., Hinojosa, J.A., 2001. Emotion, attention, and the 'negativity bias', studied through event-related potentials. International Journal of Psychophysiology 41 (1), 75–85.

Carroll, P., Sweeny, K., Shepperd, J.A., 2006. Forsaking optimism. Review of General Psychology 10 (1), 56–73.

Chung, G., Tucker, D.M., West, P., Potts, G.F., Liotti, M., Luu, P., Hartry, A.L., 1996. Emotional expectancy: brain electrical activity associated with an emotional bias in interpreting life events. Psychophysiology 33 (3), 218–233.

De Pascalis, V., Arwari, B., D'Antuono, L., Cacace, I., 2009. Impulsivity and semantic/emotional processing: an examination of the N400 wave. Clinical Neurophysiology 120 (1), 85–92.

DeLong, K.A., Urbach, T.P., Groppe, D.M., Kutas, M., 2011. Overlapping dual ERP responses to low cloze probability sentence continuations. Psychophysiology, doi:10.1111/j.1469-8986.2011.01199.x, pp. 1-5 (early view online version).

DeLong, K.A., Urbach, T.P., Kutas, M., 2005. Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. Nature Neuroscience 8 (8), 1117–1121.

Diener, E., Lucas, R.E., Scollon, C.N., 2006. Beyond the hedonic treadmill: revising the adaptation theory of well-being. American Psychologist 61 (4), 305–314.

Federmeier, K.D., 2007. Thinking ahead: the role and roots of prediction in language comprehension. Psychophysiology 44 (4), 491–505.

Federmeier, K.D., Kirson, D.A., Moreno, E.M., Kutas, M., 2001. Effects of transient, mild mood states on semantic memory organization and use: an event-related potential investigation in humans. Neuroscience Letters 305 (3), 149–152.

Federmeier, K.D., Kutas, M., 1999. A rose by any other name: long-term memory structure and sentence processing. Journal of Memory and Language 41 (4), 469–495.

Federmeier, K.D., Wlotko, E.W., De Ochoa-Dewald, E., Kutas, M., 2007. Multiple effects of sentential constraint on word processing. Brain Research 1146, 75–84.
Fischler, I., Bradley, M., 2006. Event-related potential studies of language and emotion: words, phrases, and task effects. Understanding Emotions 156, 185–203.
Golub, S.A., Gilbert, D.T., Wilson, T.D., 2009. Anticipating one's troubles: the costs and benefits of negative expectations. Emotion 9 (2), 277–281.
Gratton, G., Coles, M.G., Donchin, E., 1983. A new method for off-line removal of ocular artifact. Electroencephalography and Clinical Neurophysiology 55 (4), 468–484.
Hagoort, P., Hald, L., Bastiaansen, M., Petersson, K.M., 2004. Integration of word meaning and world knowledge in language comprehension. Science 304 (5669), 438–441.
Hald, L.A., Steenbeek-Planting, E.G., Hagoort, P., 2007. The interaction of discourse context and world knowledge in online sentence comprehension. Evidence from the N400. Brain Research 1146, 210–218.
Herbert, C., Junghofer, M., Kissler, J., 2008. Event related potentials to emotional adjectives during reading. Psychophysiology 45 (3), 487–498.
Holt, D.J., Lynn, S.K., Kuperberg, G.R., 2008. Neurophysiological correlates of comprehending emotional meaning in context. Journal of Cognitive Neuroscience 21 (11), 2245–2262.
Ito, T.A., Cacioppo, J.T., 2000. Electrophysiological evidence of implicit and explicit categorization processes. Journal of Experimental Social Psychology 36 (6), 660–676.
Ito, T.A., Larsen, J.T., Smith, N.K., Cacioppo, J.T., 1998. Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. Journal of Personality and Social Psychology 75 (4), 887–900.
Janoff-Bulman, R., 1989. Assumptive worlds and the stress of traumatic events: applications of the schema construct. Social Cognition 7 (Special Issue: Social Cognition and Stress), 113–136.
Kissler, J., Assadollahi, R., Herbert, C., 2006. Emotional and semantic networks in visual word processing: insights from ERP studies. Understanding Emotions 156, 147–183.
Kissler, J., Herbert, C., Peyk, P., Junghofer, M., 2007. Buzzwords: early cortical responses to emotional words during reading. Psychological Science 18 (6), 475–480.
Kissler, J., Koessler, S., 2011. Emotionally positive stimuli facilitate lexical decisions – an ERP study. Biological Psychology 86 (3), 254–264.
Koo, M., Algoe, S.B., Wilson, T.D., Gilbert, D.T., 2008. It's a wonderful life: mentally subtracting positive events improves people's affective states, contrary to their affective forecasts. Journal of Personality and Social Psychology 95 (5), 1217–1224.
Kutas, M., 1987. Event-related brain potentials (ERPs) elicited during rapid serial visual presentation of congruous and incongruous sentences. Electroencephalography and Clinical Neurophysiology Supplement 40, 406–411.
Kutas, M., DeLong, K.A., Smith, N.J., 2011. A look around at what lies ahead: prediction and predictability in language processing. In: Bar, M. (Ed.), Predictions in the Brain: Using Our Past to Generate a Future. Oxford University Press, pp. 190–207.
Kutas, M., Federmeier, K.D., 2000. Electrophysiology reveals semantic memory use in language comprehension. Trends in Cognitive Sciences 4 (12), 463–470.
Kutas, M., Federmeier, K.D., 2011. Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). Annual Review of Psychology 62, 621–647.
Kutas, M., Hillyard, S.A., 1980a. Event-related brain potentials to semantically inappropriate and surprisingly large words. Biological Psychology 11 (2), 99–116.
Kutas, M., Hillyard, S.A., 1980b. Reading senseless sentences: brain potentials reflect semantic incongruity. Science 207 (4427), 203–205.
Kutas, M., Hillyard, S.A., 1984. Brain potentials during reading reflect word expectancy and semantic association. Nature 307 (5947), 161–163.
Kutas, M., Lindamood, T.E., Hillyard, S.A. (Eds.), 1984. Word Expectancy and Event-Related Brain Potentials During Sentence Processing. Erlbaum, Hillsdale, NJ.
Norem, J.K. (Ed.), 2001. The Positive Power of Negative Thinking. Basic Books, NY.
Norem, J.K., Chang, E.C., 2002. The positive psychology of negative thinking. Journal of Clinical Psychology 58 (9), 993–1001.
Oldfield, R.C., 1971. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia 9 (1), 97–113.
Osterhout, L., 1997. On the brain response to syntactic anomalies: manipulations of word position and word class reveal individual differences. Brain and Language 59 (3), 494–522.
Paulmann, S., Kotz, S.A., 2008. An ERP investigation on the temporal dynamics of emotional prosody and emotional semantics in pseudo- and lexical-sentence context. Brain and Language 105 (1), 59–69.
Scheier, M.F., Carver, C.S., 1985. Optimism, coping, and health: assessment and implications of generalized outcome expectancies. Health Psychology 4 (3), 219–247.
Scheier, M.F., Carver, C.S., 1987. Dispositional optimism and physical well-being – the influence of generalized outcome expectancies on health. Journal of Personality 55 (2), 169–210.
Scheier, M.F., Carver, C.S., Bridges, M.W., 1994. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the Life Orientation Test. Journal of Personality and Social Psychology 67 (6), 1063–1078.
Schirmer, A., Kotz, S.A., Friederici, A.D., 2002. Sex differentiates the role of emotional prosody during word processing. Brain Research Cognitive Brain Research 14 (2), 228–233.
Sebastián-Gallés, N., Martí, M.A., Carreiras, M., Cuetos, F., 2000. Lexesp: Una base de datos informatizada del español. Edicions de la Universitat de Barcelona, Barcelona, Spain.
Shepperd, J.A., McNulty, J.K., 2002. The affective consequences of expected and unexpected outcomes. Psychological Science 13 (1), 85–88.
Sweeny, K., Carroll, P.J., Shepperd, J.A., 2006. Is optimism always best?: Future outlooks and preparedness. Current Directions in Psychological Science 15 (6), 302–306.
Sweeny, K., Shepperd, J.A., 2007. Do people brace sensibly? Risk judgments and event likelihood. Personality and Social Psychology Bulletin 33 (8), 1064–1075.
Taylor, S.E., Brown, J.D., 1988. Illusion and well-being: a social psychological perspective on mental health. Psychological Bulletin 103 (2), 193–210.
Taylor, W.L., 1953. Cloze procedure: a new tool for measuring readability. Journalism Quarterly 30, 415–433.
Vaish, A., Grossmann, T., Woodward, A., 2008. Not all emotions are created equal: the negativity bias in social–emotional development. Psychological Bulletin 134 (3), 383–403.
Van Berkum, J.J., Brown, C.M., Zwitserlood, P., Kooijman, V., Hagoort, P., 2005. Anticipating upcoming words in discourse: evidence from ERPs and reading times. Journal of Experimental Psychology: Learning, Memory, and Cognition 31 (3), 443–467.
Van Berkum, J.J.A., Holleman, B., Nieuwland, M., Otten, M., Murre, J., 2009. Right or wrong? The brain's fast response to morally objectionable statements. Psychological Science 20 (9), 1092–1099.
Vázquez, C., Sanz, J., 1997. Fiabilidad y valores normativos de la versión española del Inventario para la Depresión de Beck de 1978. Clínica y Salud 8, 403–422.
Watson, D., Clark, L.A., Tellegen, A., 1988. Development and validation of brief measures of positive and negative affect: the PANAS scales. Journal of Personality and Social Psychology 54 (6), 1063–1070.
Wicha, N.Y.Y., Moreno, E.M., Kutas, M., 2004. Anticipating words and their gender: an event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. Journal of Cognitive Neuroscience 16 (7), 1272–1288.