Applied Psycholinguistics (2024), **45**, 979–999
doi:10.1017/S0142716424000365

CAMBRIDGE UNIVERSITY PRESS

ORIGINAL ARTICLE

A negative mood facilitates complex semantic processing in a second language

Marcin Naranowicz[1,2] and Katarzyna Jankowiak[1]

[1]Department of Psycholinguistic Studies, Faculty of English, Adam Mickiewicz University, Poznań, Poland and [2]Cognitive Neuroscience Center, Adam Mickiewicz University, Poznań, Poland
Corresponding author: Marcin Naranowicz; Email: marcin.naranowicz@amu.edu.pl

(Received 13 June 2023; revised 28 May 2024; accepted 4 October 2024; first published online 14 November 2024)

Abstract
Research has demonstrated that positive and negative moods may differently affect semantic processing due to the activation of mood-dependent thinking. Interestingly, recent studies have indicated that the interplay between mood and semantic processing may also be modulated by the language of operation (native [L1] vs. second language [L2]). Still, it remains an open question if and how mood interacts with varying depths of semantic processing, particularly in bilinguals. Here, we show that a negative mood may differently modulate shallow and deep semantic processing in bilinguals at a behavioral level. In two experiments, Polish–English bilinguals, induced into positive and negative moods, performed a lexical decision task (marking shallow semantic processing; Experiment 1) and a semantic decision task (marking deep semantic processing; Experiment 2) with sentences in L1 and L2 of varying semantic complexity: literal, novel metaphoric, and anomalous sentences. While no interactive mood–language effect was observed for shallow semantic processing, we found faster semantic judgments when bilinguals were in a negative relative to positive mood in L2, but not L1, for deep semantic processing. These findings suggest that a negative mood may activate more analytical and effort-maximizing thinking in L2, yet only when the linguistic content requires deeper understanding.

Keywords: bilingualism; depth of processing; mood; novel metaphor; semantic processing

Introduction

Mood, defined as a slowly changing background affective state that can be of more positive or negative valence (Forgas, 2017), has been shown to modulate cognitive mechanisms engaged in language comprehension (e.g., Pinheiro et al., 2013; Vissers et al., 2013; Wang et al., 2016; see Naranowicz, 2022 for a review). While a positive mood has been indicated to trigger a broad and heuristics-based processing of semantic information, a negative mood has been linked with a more analytical (i.e., detail-oriented) and narrow processing style. Crucially, recent evidence has indicated that the degree of such effects is likely to be modulated by the language of operation (native [L1] vs. second language [L2]; Kissler & Bromberek-Dyzman, 2021; Jankowiak et al., 2022; Naranowicz et al., 2022a, 2022b, 2023). To the best of our knowledge, however, the influence that mood exerts on semantic processes in bilingualism has not yet been studied by means of comparing different depths of semantic processing. Such investigation might provide crucial insights into how one's affective state influences different levels of semantic processing engaged in meaning analysis in L1 versus L2. Therefore, in two behavioral experiments, we tested how a positive and negative mood modulates shallow and deep semantic mechanisms while processing sentences of different semantic complexity. To this end, Polish–English bilinguals were presented with three types of L1 and L2 sentences that differed on the semantic complexity continuum—literal, novel metaphoric, and anomalous sentences—and performed either a lexical decision task (LDT; marking shallow semantic processing; Experiment 1) or a semantic decision task (SDT; marking deep semantic processing; Experiment 2).

Levels of semantic processing

In line with the levels of processing view (Craik & Lockhart, 1972), human memory is organized in a hierarchical manner, with different levels of perceptual processing. While preliminary stages involve the analyses of physical and sensory features of the stimulus, later stages are responsible for meaning extraction and consequently require a greater degree of semantic analysis (Craik & Lockhart, 1972). The activation of semantic attributes of a linguistic input (be it a word or a sentence) is a highly automatic process that is triggered unconsciously and results in the meaning of a stimulus being accessed instantaneously (MacLeod, 1991; Schnuerch et al., 2016). Yet, the depth of meaning processing (i.e., the extent of semantic analysis) is assumed to be modulated by higher-level cognitive influences, including top-down attention, intentions, and task requirements (Kiefer & Martens, 2010; Kreitz et al., 2015; Vachon et al., 2019). For instance, the tasks that direct attention to non-semantic properties of the stimulus have been shown to attenuate semantic priming effects, therefore indicating that the degree of semantic activation is influenced by task specificity (Besner et al., 1997; Vachon & Jolicœur, 2012; Vachon et al., 2019).

The two tasks that are frequently compared against one another in how deep versus shallow semantic processes they evoke are an SDT and an LDT, respectively. In an SDT, participants decide whether the presented sentence is meaningful or meaningless, which thus requires the activation of stored semantic representations from long-term memory, leading to an overt (deep) semantic analysis (Craik & Lockhart, 1972; Vachon et al., 2019). In an LDT, on the other hand, participants decide whether a string of letters represents a real word or a non-word, therefore activating only implicit (shallow) semantic processing (Rissman et al., 2003). Consequently, semantics-driven effects have been found to be less pronounced in an LDT relative to an SDT, as reflected in shorter semantic priming effects (Becker et al., 1997) or lack thereof (Perea & Rosa, 2002; Vigliocco et al., 2004) when participants performed an LDT. Consequently, it has been postulated that an SDT, compared to an LDT, evokes more qualitative semantic judgments, due to the greater depth of semantic analysis it evokes (Rotaru et al., 2018).

Mood and semantic processing in L1 and L2

Previous research on mood and language processing has indicated that both a positive and negative mood may lead to processing advantages, depending on situational needs and task requirements. On the one hand, behavioral and electrophysiological (EEG) evidence has demonstrated that a positive relative to negative mood may enhance the mechanisms engaged in semantic processing (see Naranowicz, 2022 for a review). Such a processing advantage in a positive mood is consistent with the *affect-as-information* framework (Schwarz & Clore, 1983), and has been linked to stronger activation of semantic associations (e.g., Bolte et al., 2003; Pinheiro et al., 2013), a greater breadth of attentional focus (e.g., Chwilla et al., 2011; Sakaki et al., 2011), directing attention to critical contextual information (e.g., Vissers et al., 2013; Wang et al., 2016), and reliance on general knowledge structures (e.g., Bless et al., 1996; Vissers et al., 2013). On the other hand, a negative mood has also been found to facilitate information processing (see Forgas 2013, 2017 for reviews), including semantic processing (see Naranowicz, 2022 for a review), when a task at hand requires constructing systematic semantic associations (Hesse & Spies, 1996), reliance on previous knowledge (Vissers et al., 2013; Jankowiak et al., 2022), reliance on stereotypes (Unkelbach et al., 2008), or greater attention to incoming information (Forgas, 2015). Consequently, it might be hypothesized that the facilitatory effect of a negative mood, as compared to a positive mood, on cognitive performance may be modulated by task complexity, with a negative mood potentially facilitating deep semantic analysis.

Mood–semantics interactions have recently been studied in a bilingual context, revealing that L1 and L2 comprehension may also be altered by a bilingual's affective state (e.g., García-Palacios et al., 2018; Kissler & Bromberek-Dyzman, 2021; Jankowiak et al., 2022; Naranowicz et al., 2022a, 2022b, 2023). For instance, in an SDT-based experiment, Jankowiak et al. (2022) tested how a film-induced positive and negative mood affects EEG responses to L1 and L2 literal, novel metaphoric, and anomalous sentences in proficient Polish–English bilinguals. They found that anomalous sentences, built upon general knowledge violations, required attenuated semantic integration and re-analysis mechanisms in both L1 and L2 in a negative but not positive mood. Such results point to a negative mood inhibiting heuristics-based and promoting analytical and effort-maximizing processing (Bless, 2001; Vissers et al., 2013), thus decreasing meaning re-evaluation, irrespective of the language of operation. Crucially, though growing evidence has pointed to differential mood effects on semantic processing in a monolingual and bilingual context, it remains an open question if and how the relationship between mood and semantic processing can be affected by the depth of semantic processing.

Importantly, studying semantic processing benefits from extending the traditional approach, which focused almost exclusively on a binary comparison between semantically correct and incorrect conditions, to the investigation of different levels of semantic complexity. Research examining the role of semantic complexity in language processing mostly employs, in addition to the classical meaningful (literal) and meaningless (anomalous) items, (unfamiliar) metaphoric language, whose processing requires complex cross-domain mappings (Gibbs & Colston, 2012; Jankowiak et al., 2022). Consequently, novel metaphors

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

elicit more complex semantic analyses relative to literal sentences, though both conditions represent meaningful items. Such a graded effect of semantic complexity was previously reported in event-related potential (ERP) studies, whereby a linear effect from literal to novel metaphoric and finally to anomalous sentences was observed at the stage of both lexico-semantic access (marked by the N400 ERP component) and final meaning integration (indexed by the late positive complex; e.g., Tang et al., 2017; Jankowiak et al., 2021; Wang & Jankowiak, 2023). Therefore, in the present study, we aim to test semantic mechanisms from the perspective of different levels of both semantic processing (deep vs. shallow tasks) and semantic complexity (literal vs. novel metaphoric vs. anomalous sentences), thus offering thorough insights into how mood can modulate meaning comprehension.

The present study

Building upon previous research, here we make the first attempt to investigate how a positive and negative mood modulates shallow and deep semantic mechanisms when participants process sentences of different semantic complexity. To this end, we elicited a positive and negative mood with affectively evocative films in Polish–English bilinguals, who performed either an LDT marking shallow semantic processing (Experiment 1) or an SDT marking deep semantic processing (Experiment 2) with L1 and L2 literal, novel metaphoric, and anomalous sentences. The three sentence types, representing varying semantic complexity, ensured that deep semantic processing was activated, increasing cognitive demands invested in their semantic analysis. Building upon previous research, we predicted that a positive and negative mood may differently affect shallow and deep semantic processing, which may further be modulated by the language of operation. First, a positive as opposed to negative mood was expected to facilitate shallow semantic processing regardless of the language of operation, which would be indicative of the activation of semantic associations (e.g., Bolte et al., 2003; Pinheiro et al., 2013) as well as attention-driven mechanisms (e.g., Chwilla et al., 2011; Sakaki et al., 2011) in a positive mood. In Experiment 1, such an effect was expected to be reflected in enhanced behavioral responses in a positive relative to negative mood in both L1 and L2 in an LDT (Hypothesis 1). Then, a negative as opposed to positive mood was predicted to facilitate deep semantic processing, which would indicate the activation of analytical and effort-maximizing processing and inhibited reliance on prior knowledge and heuristics (e.g., Vissers et al., 2013; Jankowiak et al., 2022) in a negative mood (see Naranowicz, 2022 for a review). Given that L2 relative to L1 processing is overall more cognitively taxing in L1-dominant bilinguals (Iacozza et al., 2017; García-Palacios et al., 2018; Naranowicz et al., 2022b), this negative mood-driven facilitatory effect was predicted to be stronger in L2 than L1. In Experiment 2, this would be reflected in enhanced behavioral responses in a negative relative to positive mood in an SDT, with the effect being more pronounced in L2 than L1 (Hypothesis 2).

Table 1. Participants' demographic and linguistic data (means with 95% confidence intervals)

	Experiment 1	Experiment 2
Age	22.0 (21.4, 22.5)	21.3 (20.6, 21.9)
Handedness[a]	72.3 (53.1, 91.5)	81.0 (64.8, 97.2)
Depression[b]	23.7 (15.7, 31.7)	13.6 (10.1, 17.1)
Anxiety[b]	13.3 (7.14, 19.5)	8.0 (4.7, 11.3)
Stress[b]	33.0 (25.5, 40.6)	21.7 (16.5, 27.0)
L2 proficiency[c]	83.5 (80.5, 86.4)	86.9 (83.6, 90.3)
L1 proficiency[d]	96.6 (94.7, 98.5)	95.3 (93.1, 97.5)
L2 proficiency[d]	90.0 (87.6, 92.3)	84.5 (81.9, 87.0)
L1 dominance[d]	62.5 (60.0, 65.1)	60.9 (58.8, 62.9)
L2 dominance[d]	58.6 (56.5, 60.7)	55.4 (52.4, 58.4)
L1 immersion[d]	92.5 (91.6, 93.4)	93.2 (92.2, 94.2)
L2 immersion[d]	60.8 (58.8, 62.7)	57.0 (53.2, 60.8)
Age of L2 acquisition[d]	7.8 (7.2, 8.4)	8.1 (7.1, 9.0)

Note: The table includes only the data for the final sample.
[a]Edinburgh Handedness Inventory (Oldfield, 1971): left-handedness (–100 to –28), ambidexterity (–29–48), and right-handedness (48–100).
[b]DASS-21 (Lovibond & Lovibond, 1995, translated into Polish by Makara-Studzińska et al.): normal (0–21), mild (22–31), moderate (32–48), severe (49–64), and extremely severe (65–100) levels of depression, anxiety, and stress (percentages).
[c]LexTALE (Lemhöfer & Broersma, 2012; percentages).
[d]Language History Questionnaire 3.0 (Li et al., 2020, as translated into Polish by Naranowicz & Witczak): the proficiency, dominance, and immersion scores (percentages); age of acquisition (years).

Methods

Participants

Seventy-four Polish (L1) learners of English (L2) were randomly assigned to either shallow semantic processing-based Experiment 1 ($n = 36$) or deep semantic processing-based Experiment 2 ($n = 38$), 4 of whom were excluded from the analyses due to very low overall response accuracy (i.e., below 20%). Consequently, the final sample included 35 participants aged 18–27 years in each experiment (see Table 1). Note that the power analysis suitable for statistical models with crossed-random structure (Westfall et al., 2014) indicated that participation of 15 bilinguals would yield a power of .80 to detect medium-to-large effects (Cohen's $d > .50$). All participants were women, given the previous studies pointing to sex-dependent mood effects on language processing (Federmeier et al., 2001; Naranowicz et al., 2023). In line with de Groot (2011), participants were classified as proficient L1-dominant Polish–English bilinguals, who had acquired English in a formal learning context and had never lived in the L2 environment (see Table 1). All participants had normal or corrected-to-normal vision and hearing and no neurological, mood, psychiatric, or language disorders. Moreover, they were in a generally good affective state, as corroborated by the Depression, Anxiety and Stress Scale – 21 Items

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

(DASS-21; Lovibond & Lovibond, 1995; see Table 1). For their participation, participants received extra credit points.

Materials

Mood-inducing stimuli

To experimentally induce the targeted positive and negative mood, participants were exposed to 11 positive and 11 negative mood-inducing films in Experiment 1 (shallow semantic processing) and 8 positive and 8 negative mood-inducing films in Experiment 2 (deep semantic processing). These were 90-second, physiologically arousing, non-narrative, and affectively evocative animated films. They were adapted from Naranowicz et al. (2023), where they were rated on 7-point valence (1 = *inducing a very negative mood*, 7 = *inducing a very positive mood*) and arousal (1 = *very physiologically unarousing*, 7 = *very physiologically arousing*) scales. The positive compared to negative mood-inducing films employed in Experiment 1 were rated significantly higher on the valence scale ($M_{PositiveFilms} = 5.05$, 95% CI [4.65, 5.45]; $M_{NegativeFilms} = 2.10$, 95% CI [1.72, 2.49]), $b = -2.95$, SE = .25, $t(22.2) = -11.50$, $p < .001$, with no difference between the two film types in arousal ratings ($M_{PositiveFilms} = 4.19$, 95% CI [3.71, 4.67]; $M_{NegativeFilms} = 4.27$, 95% CI [3.82, 4.72]), $b = .08$, SE = .27, $t(23.4) = .29$, $p = .773$. Similarly, the positive compared to negative mood-inducing films employed in Experiment 2 were also rated significantly higher on the valence scale ($M_{PositiveFilms} = 5.07$, 95% CI [4.63, 5.50]; $M_{NegativeFilms} = 2.09$, 95% CI [1.66, 2.52]), $b = -2.98$, SE = .28, $t(16.4) = -10.70$, $p < .001$, with no difference between the two film types in arousal ratings ($M_{PositiveFilms} = 4.15$, 95% CI [3.63, 4.67]; $M_{NegativeFilms} = 4.27$, 95% CI [3.77, 4.78]), $b = .12$, SE = .30, $t(17.5) = .41$, $p = .683$. To sustain the evoked targeted mood, each selected film was additionally divided into two 45-second fragments, which resulted in the presentation of 44 film fragments in both mood conditions in Experiment 1 (i.e., 33 minutes) and 32 film fragments in both mood conditions in Experiment 2 (i.e., 24 minutes).

Linguistic stimuli

The linguistic stimuli included 180 Polish (L1) and 180 English (L2) sentences divided into three categories: 60 novel metaphors (e.g., *My heart is a drawer.; Bacteria are fighters.; Motivation is an engine.*), 60 literal sentences (e.g., *This piece of furniture is a drawer.; These boxers are fighters.; This machine is an engine.*), and 60 anomalous sentences (e.g., *A bug is a drawer.; Gifts are fighters. A frog is an engine.)* in each language. The linguistic stimuli were adopted from a database by Jankowiak (2020) that provides a set of pre-tested novel metaphors and literal and anomalous sentences. The stimuli were controlled for their level of meaningfulness, familiarity, and metaphoricity in norming tests on Polish and English native speakers. Furthermore, critical words were all concrete nouns and were controlled for their frequency (SUBTLEX-PL, Mandera et al., 2015; SUBTLEX-UK, van Heuven et al., 2014; $M = 3.93$, $SD = .56$), the number of letters ($M = 6.57$, $SD = 1.45$), and syllables ($M = 2.34$, $SD = .48$), as well as a cognate status (Jankowiak, 2020). All sentences were declarative and emotionally neutral. The mean sentence lengths of the stimuli ranged from 3 to 5 (novel nominal metaphors: $M = 3.28$, $SD = .50$; literal sentences: $M = 4.00$, $SD = .18$; anomalous sentences: $M = 3.71$, $SD = .57$).

In shallow semantic processing-based Experiment 1, in addition to the original 180 critical words per language, we added 180 pronounceable non-words in Polish (adopted from Imbir, 2015) and 180 pronounceable non-words in English (adopted from Balota et al., 2007). All of the non-words were controlled for the number of letters ($M = 7.14$, $SD = 1.47$).

Procedure

The procedure applied in the experiments was approved by the Ethics Committee for Research Involving Human Participants of Adam Mickiewicz University, Poznań. Informed consents were obtained from all participants involved in the study. Participants were first randomly assigned to either Experiment 1 (shallow semantic processing) or Experiment 2 (deep semantic processing). In both experiments, participants were seated 75 cm away from an LED monitor with a screen resolution of 1280 × 1024 pixels in dimly lit and quiet booths. E-Prime 3.0 was employed to present all stimuli and collect behavioral data.

Participants were presented with 22 positive and 22 negative mood-inducing film fragments in two separate mood blocks in Experiment 1 and 16 positive and 16 negative mood-inducing film fragments in Experiment 2. The film fragments were presented in random order in each mood block. Additionally, participants watched a 5-minute fragment of a low-arousing non-narrative nature documentary before the second mood block to neutralize their mood state. To strengthen the induced mood states, participants were additionally instructed to put themselves in the targeted mood (Rottenberg et al., 2018) and imagine themselves as one of the protagonists (Werner-Seidler & Moulds, 2012). Participants were asked to rate their current emotional state before and after each mood block. In both experiments, participants first watched 4 film fragments to elicit the targeted mood and then alternately read 20 sentences and were presented with another film fragment to sustain the evoked mood state. For this reason, participants were presented with a greater number of mood-inducing stimuli in Experiment 1 (shallow semantic processing) than in Experiment 2 (deep semantic processing).

In Experiment 1 (shallow semantic processing), participants performed an LDT, wherein they decided whether or not the final string of letters in each sentence was a real word in Polish or English. Crucially, even though participants made lexical decisions only about the final strings of letters, they were asked to read the whole sentences. In Experiment 2 (deep semantic processing), participants performed an SDT, wherein they decided if each presented sentence was meaningful or meaningless. In both experiments, participants read the same set of 180 Polish and 180 English sentences in separate language blocks, each including 60 literal, 60 anomalous, and 60 novel metaphoric sentences presented in random order. In Experiment 1, 180 Polish and 180 English filler sentences were added, each including a pronounceable non-word placed in a sentence-final position. In Experiment 2, 60 Polish and 60 English filler anomalous sentences were added to reach the same number of semantically meaningful (i.e., literal and novel metaphoric) and meaningless (i.e., anomalous) sentences. In total, participants

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

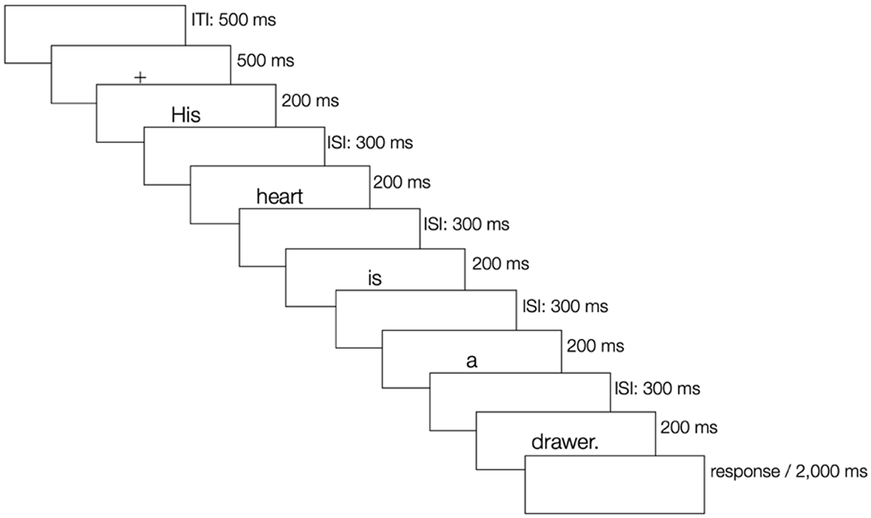

Figure 1. Time sequence of stimuli presentation in both experiments (ITI, inter-trial interval; ISI, inter-stimulus interval).

read 720 sentences in Experiment 1 and 480 sentences in Experiment 2, half of which was presented in each mood block. The order of the mood and language blocks as well as key designation were counterbalanced across participants. The time sequence of stimuli presentation is provided in Figure 1.

Data analysis

All statistical analyses were performed in R (R Core Team, 2020). In both experiments, the mood rating data analysis conformed to a 2 (Time of measure: Before vs. After mood induction) × 2 (Mood: Positive vs. Negative) within-subject design. Participants rated their current affective state using three measures: 7-point mood valence and arousal scales (i.e., bipolar dimensions) as well as the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988, adapted into Polish by Fajkowska & Marszał-Wiśniewska, 2009), employing 10 positive adjectives (i.e., positive affect) and 10 negative adjectives (i.e., negative affect; i.e., unipolar dimensions). The summed positive affect and negative affect scores were presented as a ratio to make them comparable to mood valence ratings. To ensure the effectiveness of our mood manipulation, we conducted planned comparisons by separately comparing mood ratings after induction to those before induction within each mood condition. We expected to observe increased/comparable mood ratings in the positive mood condition along with decreased mood ratings in the negative mood condition (see Naranowicz, 2022 for a review).

In both experiments, the reaction times (RTs) and accuracy rates data analyses conformed to a 2 (Mood: Positive vs. Negative) × 2 (Language: Polish [L1] vs. English [L2]) × 3 Sentence type (Literal vs. Anomalous vs. Novel metaphoric sentences) within-subject design. RTs below 200 ms and above 1,500 ms as well as those falling outside the value of 1.5 interquartile range were discarded from further

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

analyses, altogether resulting in the final rejection of 5.03% of RT and accuracy rates data in Experiment 1 (shallow semantic processing) and 3.25% in Experiment 2 (deep semantic processing).

In both experiments, the mood ratings and RT data were analyzed with linear mixed-effects models (Baayen et al., 2008; Jaeger, 2008; Barr et al., 2013; Barr, 2013) and response accuracy with generalized (logistic) linear mixed-effects model (Baayen et al., 2008; Barr, 2013; Barr et al., 2013; Jaeger, 2008), using the *lme4* package (Bates et al., 2015). Sum contrasts were applied to all categorical factors. A maximal model was first computed with a full random-effect structure, including participant- and item-related variance components for intercepts and by-participant and by-item random slopes for fixed effects (Barr et al., 2013). When the data did not support the execution of the maximal model random structure, we reduced the model complexity to arrive at a parsimonious model (Bates et al., 2015). To do so, we computed principal component analyses of the random structure and then kept the number of principal components that cumulatively accounted for 100% of the variance. b estimates and significance of fixed effects and interactions (p-values) were based on the Satterthwaite approximation for mixed-effects models (the *lmerTest* package; Kuznetsova et al., 2017). Planned and *post hoc* comparisons were calculated using the *emmeans* package (Lenth et al., 2022). All data, research materials, and analysis codes (i.e., R scripts) are available at https://osf.io/4tm5a/.

Experiment 1: lexical decision task

Results

Mood ratings

In Experiment 1, the analysis of the valence ratings showed a fixed effect of Time of measure, $b = -1.07$, SE $= .14$, $t(102.0) = -7.45$, $p < .001$, along with a Mood × Time of measure interaction, $b = -2.49$, SE $= .29$, $t(102.0) = -8.64$, $p < .001$. As expected, planned comparisons showed a decrease in the valence ratings after compared to before mood induction in the negative mood condition ($M_{BeforeMI} = 5.23$, 95% CI [4.88, 5.58]; $M_{AfterMI} = 2.91$, 95% CI [2.57, 3.26]), $b = 2.31$, SE $= .20$, $t(102.0) = 11.38$ $p < .001$, with no difference in the valence ratings in the positive mood condition ($M_{BeforeMI} = 5.17$, 95% CI [4.82, 5.52]; $M_{AfterMI} = 5.34$, 95% CI [5.00, 5.69]), $b = -.17$, SE $= .20$, $t(102.0) = -.84$, $p = .401$ (see Figure 2).

Similarly, the analysis of the PANAS ratings revealed a fixed effect of Time of measure, $b = -.26$, SE $= .06$, $t(102.0) = -4.06$, $p < .001$, along with a Mood × Time of measure interaction, $b = -.76$, SE $= .13$, $t(102.0) = -5.90$, $p < .001$. As expected, planned comparisons showed a decrease in the PANAS ratings after compared to before mood induction in the negative mood condition ($M_{BeforeMI} = 1.52$, 95% CI [1.36, 1.69]; $M_{AfterMI} = .88$, 95% CI [.72, 1.04]), $b = .64$, SE $= .09$, $t(102.0) = 7.04$, $p < .001$, with no difference in the positive mood condition ($M_{BeforeMI} = 1.46$, 95% CI [1.30, 1.63]; $M_{AfterMI} = 1.58$, 95% CI [1.42, 1.75]), $b = -.12$, SE $= .09$, $t(102.0) = -1.30$, $p = .196$ (see Figure 2).

The analysis of the arousal ratings showed only a fixed effect of Time of measure, whereby participants reported feeling more physiologically aroused after relative to before mood induction ($M_{BeforeMI} = 3.26$, 95% CI [2.88, 3.63]; $M_{AfterMI} = 3.70$, 95%

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

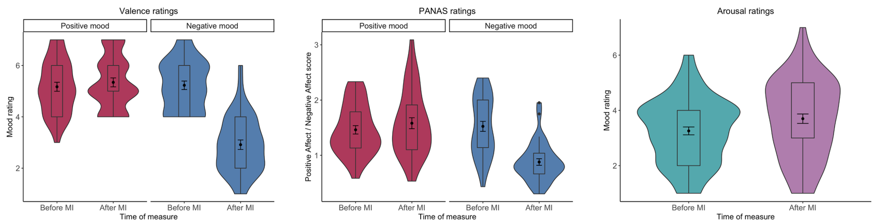

Figure 2. Experiment 1 (shallow semantic processing): The valence (left), PANAS (center), and physiological arousal (right) ratings before and after mood induction (MI) with 95% confidence intervals.

CI [3.32, 4.08]), $b = .44$, SE = .17, $t(102.0) = 2.60$, $p = .011$ (see Figure 2). All the remaining differences in the valence, PANAS, and arousal ratings were statistically non-significant, *p*s > .05.

Response accuracy

The analysis of response accuracy did not show any statistically significant differences, *p*s > .05.

Reaction times

The analysis of RTs revealed a fixed effect of Sentence type, such that literal sentences ($M = 537.97$ ms, 95% CI [520.12, 555.82]) were responded to faster than both anomalous sentences ($M = 558.68$ ms, 95% CI [540.83, 576.54]), $b = 20.71$, SE = 4.17, $t(350.9) = 4.96$, $p < .001$, and novel metaphors ($M = 557.22$ ms, 95% CI [539.37, 575.07]), $b = 19.25$, SE = 4.18, $t(350.8) = 4.60$, $p < .001$. Yet, there was no difference in RTs between anomalous and novel metaphoric sentences, $b = -1.46$, SE = 4.18, $t(351.4) = -.35$, $p = .727$. There was also a fixed effect of Language, whereby Polish (L1) sentences ($M = 539.31$ ms, 95% CI [521.06, 557.55]) were responded to faster than English (L2) sentences ($M = 563.28$ ms, 95% CI [545.32, 581.24]), $b = 23.97$, SE = 5.72, $t(65.4) = 4.19$, $p < .001$.

However, the analysis did not reveal a Mood × Language interaction. Planned comparisons confirmed that there were no statistically significant differences in RTs between the positive and negative mood conditions for both Polish (L1) ($M_{NegativeMood} = 539.92$ ms, 95% CI [521.55, 558.28]; $M_{PositiveMood} = 538.70$ ms, 95% CI [520.34, 557.05]), $b = 1.22$, SE = 2.08, $t(11536.4) = .59$, $p = .558$, and English (L2) sentences ($M_{NegativeMood} = 564.78$ ms, 95% CI [546.71, 582.86]; $M_{PositiveMood} = 561.77$ ms, 95% CI [543.69, 579.86]), $b = -3.01$, SE = 2.10, $t(11538.6) = -1.43$, $p = .152$ (see Figure 3). All remaining differences in RTs were statistically non-significant, *p*s > .05.

Discussion

In Experiment 1, targeting shallow semantic processing, Polish–English bilinguals induced into a positive and negative mood made lexical judgments regarding critical words and non-words embedded in a sentence-final position of literal, novel metaphoric, and anomalous sentences in their L1 and L2.

First, the results showed no effect of either a positive or negative mood on participants' performance in the LDT, regardless of the language of operation.

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

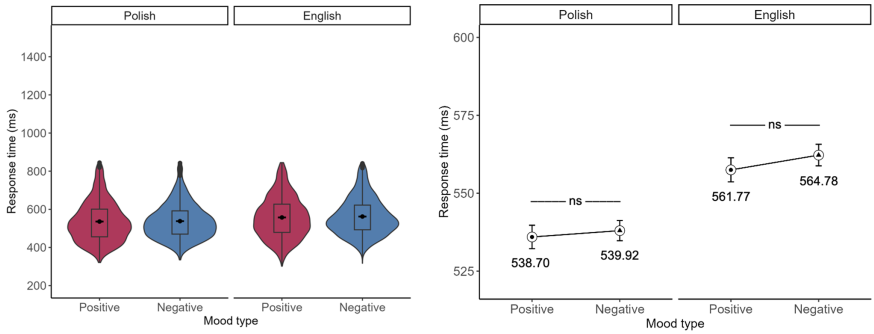

Figure 3. Experiment 1 (shallow semantic processing): Response times (ms) with 95% confidence intervals, showing the relationship between the language of operation and mood types. The violin plot (left) represents data distribution, and the line plot (right) represents the observed interactive effect.

Such findings seem interesting, given that self-reported mood ratings confirmed that participants were in the targeted positive and negative mood states and were feeling more physiologically aroused after the employed mood manipulation as compared to the baseline state. This consequently indicates that despite the effective mood manipulations, bilinguals' current affective state might not have modulated language processing patterns when performing a task requiring shallow semantic analysis.

Second, lexical judgments of the words embedded in literal sentences were faster than the ones embedded in both anomalous and novel metaphoric sentences. This indicates that though the task directed participants' attention to lexical properties only, they must have still evaluated the semantic attributes of the sentences. Consequently, when exposed to the two sentence types that potentially required meaning re-evaluation (i.e., novel metaphoric and anomalous sentences), participants needed more time to decide on whether a critical word represented a real word or a non-word. Crucially, as expected, the presence of temporal differences in responses to the three sentence types also indicates that participants implicitly processed the meaning of the entire sentences, even though the LDT at hand required making decisions only about the final string of letters (i.e., a target word or a non-word).

Finally, participants' lexical judgments of the words embedded in Polish (L1) sentences were faster than those embedded in English (L2) sentences. This pattern is in line with previous research consistently showing longer processing time in L2 than L1 (e.g., de Groot et al., 2002; Jankowiak, 2019) due to the slower and less automatic activation of L2 representations (Dijkstra & van Heuven, 2002).

The aim of Experiment 2 was to further test how participants' mood modulates L1 and L2 processing when performing a task requiring deep semantic analysis (i.e., an SDT).

Experiment 2: semantic decision task

Results

Mood ratings

In Experiment 2, the analysis of the valence ratings showed fixed effects of both Mood, $b = -1.13$, $SE = .14$, $t(102.0) = -7.84$, $p < .001$, and Time of measure,

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

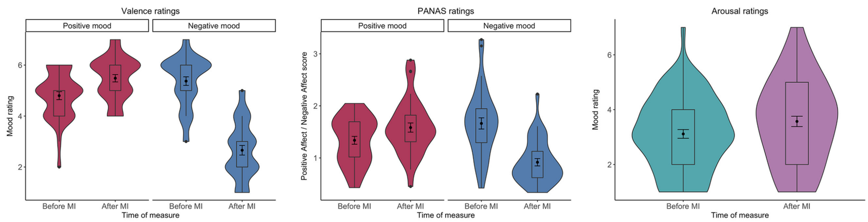

Figure 4. Experiment 2 (deep semantic processing): The valence (left), PANAS (center), and physiological arousal (right) ratings before and after mood induction (MI) with 95% confidence intervals.

$b = -1.01$, SE = .14, $t(102.0) = -7.04$, $p < .001$, along with a Mood × Time of measure interaction, $b = -3.40$, SE = .29, $t(102.0) = -11.81$, $p < .001$. As expected, planned comparisons showed a decrease in the mood valence ratings after compared to before mood induction in the negative mood condition ($M_{BeforeMI} = 5.37$, 95% CI [5.04, 5.50]; $M_{AfterMI} = 2.66$, 95% CI [2.33, 2.98]), $b = -2.71$, SE = .20, $t(102.0) = -13.33$, $p < .001$, along with an increase after compared to before mood induction in the positive mood condition ($M_{BeforeMI} = 4.80$, 95% CI [4.47, 5.13]; $M_{AfterMI} = 5.49$, 95% CI [5.16, 5.81]), $b = .69$, SE = .20, $t(102.0) = 3.37$, $p < .001$ (see Figure 4).

Similarly, the analysis of the PANAS ratings revealed fixed effects of both Mood, $b = -.17$, SE = .06, $t(102.0) = -2.83$, $p = .005$, and Time of measure, $b = -.25$, SE = .06, $t(102.0) = -4.16$, $p < .001$, along with a Mood × Time of measure interaction, $b = -.99$, SE = .12, $t(102.0) = -8.22$, $p < .001$. As expected, planned comparisons showed a decrease in the PANAS ratings after compared to before mood induction in the negative mood condition ($M_{BeforeMI} = 1.66$, 95% CI [1.49, 1.84]; $M_{AfterMI} = .92$, 95% CI [.75, 1.09]), $b = -.75$, SE = .09, $t(102.0) = -8.75$, $p < .001$, along with an increase after compared to before mood induction in the positive mood condition ($M_{BeforeMI} = 1.34$, 95% CI [1.17, 1.51]; $M_{AfterMI} = 1.58$, 95% CI [1.41, 1.76]), $b = .24$, SE = .09, $t(102.0) = 2.87$, $p < .001$ (see Figure 4).

The analysis of the arousal ratings showed only a fixed effect of Time of measure, whereby participants reported feeling more physiologically aroused before relative to after mood induction ($M_{BeforeMI} = 3.11$, 95% CI [2.71, 3.52]; $M_{AfterMI} = 3.57$, 95% CI [3.17, 3.97]), $b = .46$, SE = .21, $t(102.0) = 2.21$, $p = .030$ (see Figure 4). All the remaining differences in the valence, PANAS, and arousal ratings were statistically non-significant, $p > .05$.

Response accuracy

The analysis of response accuracy showed a fixed effect of Sentence type, such that anomalous sentences ($M = 98.44\%$, 95% CI [98.01, 98.89]) were responded to with greater accuracy than both literal sentences ($M = 85.84\%$, 95% CI [84.78, 86.92]), $b = 3.56$, SE = .46, $z = 7.67$, $p < .001$, and novel metaphors ($M = 37.63\%$, 95% CI [36.11, 39.18]), $b = -6.83$, SE = .57, $z = -12.03$, $p < .001$. Moreover, literal sentences were also responded to with greater accuracy than novel metaphors, $b = -3.28$, SE = .46, $z = -12.70$, $p < .001$.

Moreover, the analysis showed a Sentence type × Language interaction. *Post hoc* comparisons revealed that Polish (L1) literal sentences were responded to with

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

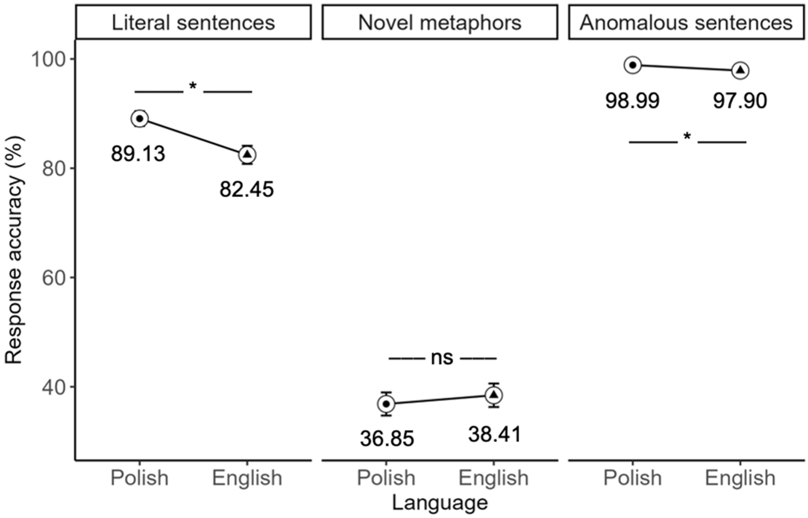

Figure 5. Experiment 2 (deep semantic processing): Accuracy rates (%) with 95% confidence intervals, showing the relationship between the language of operation and sentence types.

greater accuracy than English (L2) literal sentences (M_{Polish} = 89.13%, 95% CI [87.78, 90.48]; $M_{English}$ = 82.45%, 95% CI [80.80, 84.10]), b = –.64, SE = .27, z = –2.35, p = .019. Then, Polish (L1) anomalous sentences were responded to with greater accuracy than English (L2) anomalous sentences (M_{Polish} = 98.99%, 95% CI [98.49, 99.39]; $M_{English}$ = 97.90%, 95% CI [97.22, 98.51]), b = –.82, SE = .40, z = –2.05, p = .040. However, there was no difference in response accuracy between Polish (L1) and English (L2) novel metaphors (M_{Polish} = 36.85%, 95% CI [34.76, 39.04]; $M_{English}$ = 38.41%, 95% CI [36.30, 40.62]), b = .12, SE = .26, z = .45, p = .655 (see Figure 5). All remaining differences in response accuracy were statistically non-significant, ps $>$ .05.

Reaction times

The analysis of RTs revealed a fixed effect of Sentence type, such that novel metaphors (M = 790.57 ms, 95% CI [748.71, 832.43]) were responded to slower than both literal sentences (M = 712.11 ms, 95% CI [678.31, 745.90]), b = 78.46, SE = 9.87, t(86.7) = 7.94, p < .001, and anomalous sentences (M = 703.23 ms, 95% CI [664.80, 741.66]), b = 87.34, SE = 9.26, t(101.2) = 9.44, p < .001. Yet, there was no difference in RTs between literal and anomalous sentences, b = –8.88, SE = 9.98, t(85.0) = –.89, p = .377. There was also a fixed effect of Language, whereby Polish (L1) sentences (M = 717.81 ms, 95% CI [680.80, 754.81]) were responded to faster than English (L2) sentences (M = 752.79 ms, 95% CI [715.79, 789.80]), b = 34.99, SE = 5.87, t(354.1) = 5.96, p < .001. The analysis also revealed a fixed effect of Mood, such that participants responded faster in the negative (M = 731.04 ms, 95% CI [694.37, 767.71]) than positive mood condition (M = 739.56 ms, 95% CI [702.89, 776.23]), b = 8.53, SE = 2.95, t(11770) = 2.89, p = .004.

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

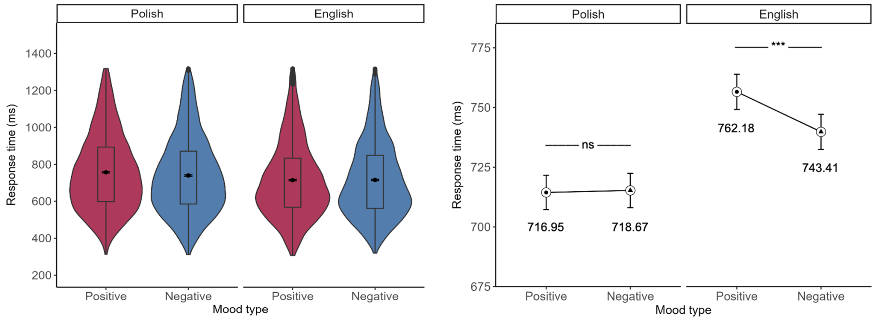

Figure 6. Experiment 2 (deep semantic processing): Response times (ms) with 95% confidence intervals, showing the relationship between the language of operation and mood types. The violin plot (left) represents data distribution, and the line plot (right) represents the observed interactive effect.

Furthermore, the analysis also showed a Mood × Language interaction. Planned comparisons revealed that English (L2) sentences were responded to faster in the negative than positive mood condition ($M_{NegativeMood} = 743.41$ ms, 95% CI [706.18, 780.64]; $M_{PositiveMood} = 762.18$ ms, 95% CI [724.94, 799.42]), $b = 18.77$, SE = 4.18, $t(11772.7) = 4.49$, $p < .001$. Yet, there was no between-mood difference in RTs for Polish (L1) sentences ($M_{NegativeMood} = 718.67$ ms, 95% CI [681.44, 755.90]; $M_{PositiveMood} = 716.95$ ms, 95% CI [679.72, 754.18]), $b = -1.72$, SE = 4.16, $t(11766.5) = -.41$, $p = .679$ (see Figure 6). All remaining differences in RTs were statistically non-significant, $ps > .05$.

Discussion

In Experiment 2, targeting deep semantic processing, Polish–English bilinguals induced into a positive and negative mood made semantic judgments of literal, novel metaphoric, and anomalous sentences in their L1 and L2.

The results revealed a facilitatory effect of a negative as opposed to positive mood on RTs, therefore indicating that a negative mood might have promoted analytical and effort-maximizing processing (see Naranowicz, 2022 for a review). Moreover, such facilitation of RTs may be related to inhibited heuristics-based thinking and reduced reliance on prior knowledge in a negative relative to positive mood (Vissers et al., 2013; Jankowiak et al., 2022), leading to overall faster semantic judgments. Also, the results demonstrated that such temporal facilitation of semantic judgments in a negative mood may be dependent upon the language of operation, given that the effect was particularly driven by between-mood differences in L2. Similar to Experiment 1, targeting shallow semantic processing, self-reported mood ratings confirmed that participants were induced into the targeted mood states in both L1 and L2, also showing increased physiological arousal in both mood conditions, therefore confirming effective both positive and negative mood manipulations.

Furthermore, the results showed a general effect of sentence types, whereby literal and anomalous sentences were similarly faster to respond to relative to novel metaphoric sentences. Such findings are contradictory to those observed in

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

Experiment 1, where novel metaphors converged behaviorally with anomalous sentences, eliciting significantly longer RTs than the literal condition. This might therefore be indicative of more attention directed towards the semantic attributes of the presented sentences in the case of an SDT, as a result of which participants were quicker to categorize literal and anomalous sentences as meaningful and meaningless, respectively. Novel metaphors, on the other hand, remained more cognitively taxing and required meaning re-analyses in both shallow and deep semantic tasks.

Finally, the semantic judgments of Polish (L1) as compared to English (L2) sentences were faster as well as more accurate for all sentence types except for novel metaphors, which were comparably difficult to categorize as meaningful in both languages. This is in line with previous research suggesting that novel metaphoric meanings, due to their high creativity and low familiarity, are cognitively taxing irrespective of the language of operation (Jankowiak et al., 2017; Jankowiak, 2019).

General discussion

The aim of the two present experiments was to test how a positive and negative mood modulates shallow as compared to deep semantic mechanisms. To this end, Polish (L1)–English (L2) bilinguals performed either an LDT (marking shallow processing; Experiment 1) or an SDT (marking deep processing; Experiment 2) with three types of L1 and L2 sentences that differed in their semantic complexity: literal, novel metaphoric, and anomalous sentences.

Hypothesis 1 predicted that a positive relative to negative mood would facilitate shallow semantic processing, regardless of the language of operation. This would align with previous studies that have suggested the activation of semantic associations (e.g., Bolte et al., 2003; Pinheiro et al., 2013) as well as attention-driven mechanisms (e.g., Chwilla et al., 2011; Sakaki et al., 2011) in a positive mood. However, contrary to our expectations, the results of Experiment 1 revealed no mood effect on the measured behavioral responses (i.e., response accuracy and times). A possible explanation for this discrepancy lies in the specific nature of the employed LDT. In Experiment 1, we took a less conventional approach to an LDT to ensure that participants engaged only in surface-level processing of sentence meanings. Specifically, participants were asked to make lexical judgments regarding the final strings of letters (i.e., words and non-words) embedded in sentential contexts instead of single decontextualized items. In contrast, prior research pointing to facilitatory effects of a positive mood on semantic processing employed an LDT in combination with semantic priming (Storbeck & Clore, 2008), a remote association task (Bolte et al., 2003), a semantic association task (Sakaki et al., 2011), a semantic decision task (Pinheiro et al., 2013; Wang et al., 2016), and reading for comprehension (Van Berkum et al., 2013; Vissers et al., 2013). Note also that the presence of a general effect of sentence types in Experiment 1 indicates that participants read the presented sentences, as instructed, while the observed mood ratings indicate that they were in the targeted mood states. Together, such findings suggest that implicit (i.e., surface-level) processing of sentence meanings may insufficiently activate lexico-semantic representations for a positive mood effect to

https://doi.org/10.1017/S0142716424000365 Published online by Cambridge University Press

have a discernible behavioral effect on semantic memory. Future research could also employ neuroimaging techniques, particularly EEG, to further test if there is an observable positive mood effect on shallow semantic processing at a neurophysiological level.

Hypothesis 2 predicted that deep semantic processing would benefit behaviorally from a negative mood that promotes a more analytical, vigilant, and effort-maximizing processing style (see Naranowicz, 2022 for a review). Such a facilitatory effect of a negative mood was also hypothesized to be more robust in L2 than L1 due to L2 being more cognitively taxing (Iacozza et al., 2017; García-Palacios et al., 2018; Naranowicz et al., 2022b). Our results supported this hypothesis, showing overall faster semantic judgments in the negative relative to the positive mood condition in L2 but not L1 in an SDT (Experiment 2). Such a negative mood-driven facilitatory effect on deep semantic processing is in accordance with previous research suggesting that a negative mood may lead to a processing advantage when a task at hand involves controlled processing of systematic stimuli (Hesse & Spies, 1996) or reliance on prior knowledge (Vissers et al., 2013; Jankowiak et al., 2022). In Experiment 2, our participants were presented with L1 and L2 sentences of a systematic structure (*X is Y*, e.g., *This machine is an engine.*), including highly figurative novel expressions (e.g., *Motivation is an engine.*) and semantic anomalies violating pre-existing knowledge (e.g., *A frog is an engine.*). Thus, making semantic judgments about such semantically complex sentences required deep semantic processing, which was found to be enhanced behaviorally by a negative mood.

Similar to the present study, Jankowiak et al. (2022) tested EEG responses to literal, novel metaphoric, and anomalous sentences in Polish–English bilinguals induced into a positive and negative mood. They observed decreased cognitive efforts invested in semantic integration and re-evaluation of anomalous sentences (i.e., the semantic violations built upon pre-existing knowledge) in a negative but not positive mood in both L1 and L2. Such results suggest that a negative mood may inhibit heuristics-based and assimilative processing, typically associated with a positive mood, and instead promote analytical and accommodative processing (the *mood-and-general-knowledge* hypothesis; Bless, 2001; Vissers et al., 2013), irrespective of the language of operation. Bearing in mind the methodological similarities between the two pieces of research, the processing advantage at the semantic integration and re-analysis stage observed in a negative mood by Jankowiak et al. (2022) could translate further into overall faster semantic judgments in a negative compared to positive mood, as observed in Experiment 2, targeting deep semantic processing.

Moreover, the observed findings showing that mood modulations on semantic processing were only evident in an SDT and not in an LDT can be interpreted in the context of previous research on semantic effects that has employed these two tasks. Such studies have consistently demonstrated more robust semantics-driven effects in an SDT compared to an LDT (Becker et al., 1997; Perea & Rosa, 2002; Vigliocco et al., 2004), which can be attributed to the nature of the tasks themselves. Namely, unlike an LDT, an SDT requires participants to engage in deep semantic analysis and activate stored semantic representations from long-term memory (Craik & Lockhart, 1972; Vachon et al., 2019). As a result, an SDT is assumed to promote more comprehensive and in-depth semantic processing compared to an LDT

(Rotaru et al., 2018). Therefore, it appears that mood effects on semantic processing are more likely to manifest themselves when a task at hand taps into deep semantic processing.

Notably, consistent with Hypothesis 2, our findings revealed a significant processing advantage associated with deep semantic processing under a negative mood state in L2 relative to L1. This advantage was manifested in faster semantic judgments in the negative mood condition in L2, indicating a more robust facilitatory effect of a negative mood on deep semantic processing in L2 than in L1. The observed temporal advantage in semantic judgments in L2 can be linked to generally higher cognitive demands imposed by L2 semantic processing relative to L1 (Iacozza et al., 2017; García-Palacios et al., 2018; Naranowicz et al., 2022b). For instance, previous physiological research has pointed to increased physiological responding when L1-dominant bilinguals perform semantic tasks in an L2 relative to L1 mode, reflecting higher cognitive demands inherent in processing information in L2 (García-Palacios et al., 2018; Naranowicz et al., 2022b). Therefore, the present study provides novel evidence elucidating the behavioral benefits derived from processing information in L2 when bilinguals experience a negative mood, particularly in semantically complex contexts.

Moreover, the results from both Experiment 1 (shallow semantic processing) and Experiment 2 (deep semantic processing) revealed significant main effects of sentence type, yet the patterns differed for the three types of sentences. In an LDT, literal sentences evoked faster RTs compared to both anomalous and novel metaphoric sentences. In contrast, in an SDT, RTs for literal and anomalous sentences converged and were faster relative to novel metaphoric sentences. First, these findings indicate that novel metaphors might have required more cognitive effort to process compared to literal sentences, regardless of the task requirements. It therefore seems that participants engaged in semantic analysis even though the task at hand required them to focus on lexical properties only. This finding supports the notion of high automaticity in the cross-domain mapping mechanisms involved in constructing novel metaphoric meanings, which leads to increased processing demands, and consequently longer behavioral responses (Gibbs & Colston, 2012; Jankowiak, 2019). Second, the more challenging processing of anomalous sentences in an LDT compared to an SDT suggests that deep semantic processing, as activated in an SDT, facilitated the categorization of anomalous sentences as meaningless. Deeper semantic analyses might have therefore aided participants in recognizing meaning violations in anomalous sentences more efficiently.

Interestingly, the aforementioned effects of sentence types were independent of the language of operation only in Experiment 1 (shallow semantic processing). In Experiment 2 (deep semantic processing), in contrast, literal and anomalous sentence processing was facilitated in L1 relative to L2, yet this advantage did not extend to the comprehension of novel metaphors, which posed similar challenges in both languages. First, the facilitated processing of L1 relative to L2 literal and anomalous sentences in Experiment 2 suggests that deep semantic analyses may enhance the retrieval of lexical and conceptual representations from the semantic network, particularly in L1, where these links are inherently more robust (Dijkstra & van Heuven, 2002). Second, the continuous difficulty of novel metaphor processing irrespective of the language of operation aligns with previous research emphasizing the comparable cognitive resources involved in the processing of novel metaphorical meanings in both L1 and L2. Such high cognitive load invested in novel metaphor processing is attributed to the low familiarity and high creativity inherent in novel metaphors across languages (Jankowiak et al., 2017; Jankowiak, 2019).

It is important to note that the low familiarity of novel metaphors, as tested here and in previous research, is typically associated with low accuracy rates on the SDT. Given the relatively high variability in participants' creativity, paradigms employing novel metaphors often report accuracy rates close to the chance level. To address this potential limitation, we adopted a database of novel metaphors (Jankowiak, 2020) that were pretested and normed for their meaningfulness level, among other factors. Despite this, the low accuracy rates for novel metaphors in our participant sample suggest that they found it challenging to make a binary decision on whether the novel metaphor should be classified as meaningful or not. Therefore, future research should employ a multiple-choice decision task, where participants judge how much sense a given metaphor makes on a scale (e.g., from 1 to 4, indicating perfect sense, some sense, little sense, and no sense; Lai et al., 2009). This approach would allow for examining the degree of sensicality of the presented metaphors in more detail (Lai et al., 2009; Lai & Curran, 2013; see also Wang & Jankowiak, 2023).

Conclusion

The aim of the two behavioral experiments was to elucidate the interaction between a positive and negative mood and varying levels of semantic processing, while also considering the influence of the language of operation (a native vs. a second language). The findings shed light on the differential modulation of shallow and deep semantic processing under a negative mood state in both participants' L1 and L2. Notably, a facilitative effect of a negative mood on language processing was observed in an SDT, indicating that deep semantic processes may exhibit heightened susceptibility to negative mood effects, in contrast to the shallow processes involved in an LDT. Crucially, this effect was particularly evident when operating in L2, thus suggesting that a negative mood might activate more analytical and effort-maximizing cognitive processes in L2, hindering heuristics-based thinking and reliance on prior knowledge. Altogether, the two present experiments uncover intriguing insights into the interplay between a negative mood, semantic processing, and bilingualism, revealing the potential cognitive advantages of processing information in L2 under emotionally challenging circumstances. These insights offer valuable implications for theories of emotion–cognition interactions and bilingualism research.

Replication package. All data, research materials, and analysis codes (i.e., R scripts) are available at https://osf.io/4tm5a/.

Author contribution statement. **MN:** conceptualization; methodology; software; validation; formal analysis; visualization; investigation; data curation; writing—original draft; writing—review and editing. **KJ**: conceptualization; methodology; validation; writing—original draft; writing—review and editing

Competing interests. The authors declare no conflict of interest.

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, **59**(4), 390–412.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The English Lexicon project. *Behavior Research Methods*, **39**(3), 445–459.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, **68**(3), 255–278.

Barr, D. J. (2013). Random effects structure for testing interactions in linear mixed-effects models. *Frontiers in Psychology*, **4**, 328.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, **67**(1), 1–48.

Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: a computational account and empirical evidence. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(5), 1059–1082.

Besner, D., Stolz, J. A., & Boutilier, C. (1997). The Stroop effect and the myth of automaticity. *Psychonomic Bulletin & Review*, **4**, 221–225.

Bless, H., Schwarz, N., Clore, G. L., Golisano, V., Rabe, C., & Wölk, M. (1996). Mood and the use of scripts: Does a happy mood really lead to mindlessness? *Journal of Personality and Social Psychology*, **71**(4), 665–679.

Bless, H. (2001). Mood and the use of general knowledge structures. In *Theories of mood and cognition: A user's guidebook* (pp. 9–26). Mahwah, New Jersey: Lawrence Erlbaum Associates Publishers.

Bolte, A., Goschke, T., & Kuhl, J. (2003). Emotion and intuition: effects of positive and negative mood on implicit judgments of semantic coherence. *Psychological Science*, **14**(5), 416–421.

Chwilla, D. J., Virgillito, D., & Vissers, C. T. W. M. (2011). The relationship of language and emotion: N400 support for an embodied view of language comprehension. *Journal of Cognitive Neuroscience*, **23**(9), 2400–2414.

Craik, F.I.M., & Lockhart, R. S. (1972). Levels of processing: a framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, **11**, 671–684.

De Groot, A. M. B., Borgwaldt, S., Bos, M., & van den Eijnden, E. (2002). Lexical decision and word naming in bilinguals: language effects and task effects. *Journal of Memory and Language*, **47**, 91–124.

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: from identification to decision. *Bilingualism: Language and Cognition*, **5**, 175–197.

Fajkowska, M., & Marszał-Wiśniewska, M. (2009). Właściwości psychometryczne Skali Pozytywnego i Negatywnego Afektu-Wersja Rozszerzona (PANAS-X). Wstępne wyniki badań w Polskiej próbie. [Psychometric properties of the positive and negative affect schedule-expanded form (PANAS-X). The study on a Polish sample.]. *Przegląd Psychologiczny*, **52**(4), 355–387.

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.

Forgas, J. P. (2013). Don't worry, be sad! on the cognitive, motivational, and interpersonal benefits of negative mood. *Current Directions in Psychological Science*, **22**(3), 225–232.

Forgas, J. P. (2015). Why do highly visible people appear more important?: Affect mediates visual fluency effects in impression formation. *Journal of Experimental Social Psychology*, **58**, 136–141.

Forgas, J. P. (2017). Mood effects on cognition: Affective influences on the content and process of information processing and behavior. In M. Jeon (Ed.), *Emotions and affect in human factors and human-computer interaction* (pp. 89–122). Cambridge, MA: Academic Press.

García-Palacios, A., Costa, A., Castilla, D., del Río, E., Casaponsa, A., & Duñabeitia, J. A. (2018). The effect of foreign language in fear acquisition. *Scientific Reports*, **8**(1), 1.

Gibbs, J., & Colston, H. L. (2012). *Interpreting figurative meaning*. Cambridge: Cambridge University Press.

Hesse, F. W., & Spies, K. (1996). Effects of negative mood on performance: Reduced capacity or changed processing strategy? *European Journal of Social Psychology*, **26**(1), 163–168.

Iacozza, S., Costa, A., & Duñabeitia, J. A. (2017). What do your eyes reveal about your foreign language? Reading emotional sentences in a native and foreign language. *PLOS ONE*, **12**(10), e0186027.

Imbir, K. K. (2015). Affective norms for 4900 polish words reload (ANPW_R): assessments for valence, arousal, dominance, origin, significance, concreteness, imageability and, age of acquisition. *Frontiers in Psychology*, **7**, 1081.

Jaeger, T. F. (2008). Categorical data analysis: away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, **59**(4), 434–446.

Jankowiak, K., Naranowicz, M., & Thierry, G. (2022). Positive and negative moods differently affect creative meaning processing in both the native and non-native language. *Brain and Language*, **235**, 105188.

Jankowiak, K. (2019). *Lexico-semantic processing in bilingual figurative language comprehension: Behavioral and electrophysiological evidence (Wydanie I)*. Poznan: Wydawnictwo Naukowe UAM.

Jankowiak, K. (2020). Normative data for novel nominal metaphors, novel similes, literal, and anomalous utterances in Polish and English. *Journal of Psycholinguistic Research*, **49**(4), 541–569.

Jankowiak, K., Naranowicz, M., & Rataj, K. (2021). Metaphors are like lenses: electrophysiological correlates of novel meaning processing in bilingualism. *International Journal of Bilingualism*, **25**, 1–19.

Jankowiak, K., Rataj, K., & Naskręcki, R. (2017). To electrify bilingualism: electrophysiological insights into bilingual metaphor comprehension. *PLOS ONE*, **12**(4), e0175578.

Kiefer, M., & Martens, U. (2010). Attentional sensitization of unconscious cognition: task sets modulate subsequent masked semantic priming. *Journal of Experimental Psychology: General*, **139**, 464–489.

Kissler, J., & Bromberek-Dyzman, K. (2021). Mood induction differently affects early neural correlates of evaluative word processing in L1 and L2. *Frontiers in Psychology*, **11**, 588902.

Kreitz, C., Schnuerch, R., Furley, P. A., Gibbons, H., & Memmert, D. (2015). Does semantic preactivation reduce inattentional blindness? *Attention, Perception, & Psychophysics*, **77**, 759–767.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: tests in linear mixed effects models. *Journal of Statistical Software*, **82**(13), 1–26.

Lai, V., & Curran, T. (2013). ERP evidence for conceptual mappings and comparison processes during the comprehension of conventional and novel metaphors. *Brain and Language*, **127**(3), 484–496.

Lai, V., Curran, T., & Menn, L. (2009). Comprehending conventional and novel metaphors: an ERP study. *Brain Research*, **1284**(11), 145–155.

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: a quick and valid lexical test for advanced learners of English. *Behavior Research Methods*, **44**(2), 325–343.

Lenth, R. V., Buerkner, P., Herve, M., Love, J., Miguez, F., Riebl, H., & Singmann, H. (2022). *emmeans: Estimated Marginal Means, aka Least-Squares Means* (1.7.2).

Li, P., Zhang, F., Yu, A., & Zhao, X. (2020). Language history questionnaire (LHQ3): an enhanced tool for assessing multilingual experience. *Bilingualism: Language and Cognition*, **23**(5), 938–944.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: comparison of the depression anxiety stress scales (DASS) with the Beck depression and anxiety inventories. *Behaviour Research and Therapy*, **33**(3), 335–343.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin*, **109**, 163–203.

Mandera, P., Keuleers, E., Wodniecka, Z., & Brysbaert, M. (2015). Subtlex-pl: subtitle-based word frequency estimates for Polish. *Behavior Research Methods*, **47**(2), 471–483.

Naranowicz, M. (2022). Mood effects on semantic processes: behavioural and electrophysiological evidence. *Frontiers in Psychology*, **13**, 1014706.

Naranowicz, M., Jankowiak, K., & Bromberek-Dyzman, K. (2023). Mood and gender effects in emotional word processing in unbalanced bilinguals. *International Journal of Bilingualism*, **27**(1), 39–60.

Naranowicz, M., Jankowiak, K., Kakuba, P., Bromberek-Dyzman, K., & Thierry, G. (2022a). In a bilingual mood: mood affects lexico-semantic processing differently in native and non-native languages. *Brain Sciences*, **12**(3), 316.

Naranowicz, M., Jankowiak, K., & Behnke, M. (2022b). Native and non-native language contexts differently modulate mood-driven electrodermal activity. *Scientific Reports*, **12**(1), 22361.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, **9**(1), 97–113.

Perea, M., & Rosa, E. (2002). The effects of associative and semantic priming in the lexical decision task. *Psychological Research*, **66**(3), 180–194.

Pinheiro, A. P., del Re, E., Nestor, P. G., McCarley, R. W., Gonçalves, Ó. F., & Niznikiewicz, M. (2013). Interactions between mood and the structure of semantic memory: event-related potentials evidence. *Social Cognitive and Affective Neuroscience*, **8**(5), 579–594.

Rissman, J., Eliassen, J. C., & Blumstein, S. E. (2003). An event-related fMRI investigation of implicit semantic priming. *Journal of Cognitive Neuroscience*, **15**, 1160–1175.

Rotaru, A. S., Vigliocco, G., & Frank, S. L. (2018). Modeling the structure and dynamics of semantic processing. *Cognitive Science*, **42**, 2890–2917.

Rottenberg, J., Kovacs, M., & Yaroslavsky, I. (2018). Non-response to sad mood induction: Implications for emotion research. *Cognition and Emotion*, **32**(3), 431–436

Sakaki, M., Gorlick, M. A., & Mather, M. (2011). Differential interference effects of negative emotional states on subsequent semantic and perceptual processing. *Emotion*, **11**(6), 1263–1278.

Schnuerch, R., Kreitz, C., Gibbons, H., & Memmert, D. (2016). Not quite so blind: Semantic processing despite inattentional blindness. *Journal of Experimental Psychology: Human Perception and Performance*, **42**, 459–463.

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology*, **45**(3), 513–523.

Storbeck, J., & Clore, G. L. (2008). The affective regulation of cognitive priming. *Emotion*, **8**(2), 208–215.

Tang, X., Qi, S., Wang, B., Jia, X., & Ren, W. (2017). The temporal dynamics underlying the comprehension of scientific metaphors and poetic metaphors. *Brain Research*, **1655**, 33–40.

Unkelbach, C., Forgas, J. P., & Denson, T. F. (2008). The turban effect: the influence of Muslim headgear and induced affect on aggressive responses in the shooter bias paradigm. *Journal of Experimental Social Psychology*, **44**(5), 1409–1413.

Vachon, F., & Jolicœur, P. (2012). On the automaticity of semantic processing during task switching. *Journal of Cognitive Neuroscience*, **24**(3), 611–626.

Vachon, F., Marsh, J. E., & Labonte, K. (2019). The automaticity of semantic processing revisited: auditory distraction by a categorical deviation. *Journal of Experimental Psychology: General*, **149**(7), 1360–1397.

Van Berkum, J. J. A., De Goede, D., Van Alphen, P. M., Mulder, E. R., & Kerstholt, J. H. (2013). How robust is the language architecture? The case of mood. *Frontiers in Psychology*, **4**, 505.

van Heuven, W. J. B., Mandera, P., Keuleers, E., & Brysbaert, M. (2014). SUBTLEX-UK: a new and improved word frequency database for British English. *The Quarterly Journal of Experimental Psychology*, **67**(6), 1176–1190.

Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M.F. (2004). Representing the meanings of object and action words: the featural and unitary semantic space hypothesis. *Cognitive Psychology*, **48**(4) 422–488.

Vissers, C. T. W. M., Chwilla, U. G., Egger, J. I. M., & Chwilla, D. J. (2013). The interplay between mood and language comprehension: evidence from P600 to semantic reversal anomalies. *Neuropsychologia*, **51**(6), 1027–1039.

Wang, L., Zhou, B., Zhou, W., & Yang, Y. (2016). Odor-induced mood state modulates language comprehension by affecting processing strategies. *Scientific Reports*, **6**(1), 36229.

Wang, X., & Jankowiak, K. (2023). Electrophysiological insights into the role of proficiency in bilingual novel and conventional metaphor processing. *Linguistic Approaches to Bilingualism*, **13**(2), 163–189.

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.

Werner-Seidler, A., & Moulds, M. L. (2012). Mood repair and processing mode in depression. *Emotion*, **12**(3), 470–478.

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *Journal of Experimental Psychology: General*, **143**(5), 2020–2045.

Cite this article: Naranowicz, M. & Jankowiak, K. (2024). A negative mood facilitates complex semantic processing in a second language. *Applied Psycholinguistics* **45**, 979–999. https://doi.org/10.1017/S0142716424000365