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How mood influences native and non-native language processing: Behavioural and electrophysiological evidence

Jak nastrój wpływa na przetwarzanie języka rodzimego i obcego: Dowody behawioralne oraz elektrofizjologiczne

Rozprawa doktorska napisana
na Wydziale Anglistyki
Uniwersytetu im. Adama Mickiewicza w Poznaniu
pod kierunkiem dr hab. Katarzyny Bromberek-Dyzman, prof. UAM
oraz prof. Guillaume'a Thierry

Poznań, 2022

I dedicate this work to my mother, Renata,
in thanks for her unshakable faith in me.

Dedykuję tę pracę mojej mamie, Renacie,
w podziękowaniu za jej niezachwianą wiarę we mnie.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude to my PhD supervisors – dr hab. Katarzyna Bromberek-Dyzman, prof. UAM and prof. Guillaume Thierry, for their tremendous support, always believing in me, constructive feedback, and guiding me through this difficult process. It has been a true privilege working with you. Thank you for helping me become a researcher and opening new research avenues for me. I am particularly grateful for giving me much freedom in my scientific endeavours and for accepting my independent yet sensitive soul.

I would like to wholeheartedly thank Dr Katarzyna Jankowiak, who has been my partner in crime since the beginning of this journey. Thank you from the bottom of my heart for always being there for me, your sisterly support, your good heart, and never doubting me. Your knowledge, dedication, and hard work have inspired me in many ways. I feel privileged to have the opportunity to explore the uncharted waters of bilingual research with you.

I would like to extend my sincere thanks to Dr Rafał Jończyk for being the kindest person on earth. Thank you for your brotherly support, enthusiasm for research, bursting with positive energy, and always seeing the good in others.

A warm thank you to Patrycja Kakuba for being a faithful companion in this treacherous journey and her infectious enthusiasm for collecting data in the lab.

This endeavour would not have been possible without heartfelt support from my dearest friends and colleagues: Dr Halszka Bąk, Dr Aina Casaponsa, Dr Paweł Korpal, Dr Iga Krzysik, Halina Lewandowska, Olivia Molina Nieto, and Dr Olga Witczak. Thank you for your positive energy and bearing with me at different stages of this journey. I am also grateful to my fellow POWR PhD students. It was grand.

I thank my family, especially my mother Renata and sister Zosia, for their unconditional love and unshakable faith in me. I would like to thank Jacek Dajewski for his overwhelming emotional support in this tricky process, his angelic patience, and for helping me stay grounded.

Last but not least, I am extremely indebted to all my participants. Thank you for your open minds and curiosity as well as for allowing me to put you in a good… and bad mood.

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List of Research articles

The present PhD project comprises four thematically related Research articles:

Research article 1 (Naranowicz et al. 2022a)
Naranowicz, Marcin, Katarzyna Jankowiak and Katarzyna Bromberek-Dyzman. 2022. "Mood and gender effects in emotional word processing in unbalanced bilinguals", *International Journal of Bilingualism* 13670069221075646.

• doi: https://doi.org/10.1177/13670069221075646
• Supplementary materials: https://osf.io/wf8s7/

Research article 2 (Naranowicz et al. 2022b)
Naranowicz, Marcin, Katarzyna Jankowiak, Patrycja Kakuba, Katarzyna Bromberek-Dyzman and Guillaume Thierry. 2022. "In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages", *Brain Sciences* 12, 3: 316.

• doi: https://doi.org/10.3390/brainsci12030316
• Supplementary materials: https://osf.io/e3r28/

Research article 3 (Jankowiak et al. 2022)
Jankowiak, Katarzyna, Marcin Naranowicz and Guillaume Thierry. 2022. "Positive and negative moods differently affect creative meaning processing in both the native and non-native language", *Brain and Language* 235: 105188.

• doi: https://doi.org/10.1016/j.bandl.2022.105188
• Supplementary materials: https://osf.io/uksm3/

Research article 4 (Naranowicz 2022)
Naranowicz, Marcin. 2022. "Mood effects on semantic processes: Behavioural and electrophysiological evidence", *Frontiers in Psychology* 13: 1014706.

• doi: https://doi.org/10.3389/fpsyg.2022.1014706
• Supplementary materials: https://osf.io/pdf53/

Funding

The research conducted for the present PhD project was funded by three independent institutions. First, the PhD candidate was a PhD student of an interdisciplinary PhD programme “Innovative language research in interdisciplinary perspectives: Psychology, sociology, and technology” at the Faculty of English, Adam Mickiewicz University, Poznań, co-funded by the Polish National Centre for Research and Development (POWR.03.02.00-00-I004/17-01) and the Faculty of English, Adam Mickiewicz University, Poznań, Poland. The research done within Research article 1 (Naranowicz et al. 2022a) was also funded by this project. Second, research done within Research article 2 (Naranowicz et al. 2022b) and Research article 4 (Naranowicz 2022) was funded by the National Science Centre, Poland under a research grant entitled “The influence of mood on semantic processes in bilingualism: An ERP study” (Preludium, 2018/31/N/HS2/00120, 2019–2022) awarded to the PhD candidate. Third, the research done within Research article 3 (Jankowiak et al. 2022) was funded by Adam Mickiewicz University, Poznań, Poland within the Excellence Initiative – Research University programme under a research grant entitled “Neurophysiological correlates of mood and novel meaning processing in bilingualism” (Minigrant doktorancki, 017/02/SNJL/0001, 2021–2022) also awarded to the PhD candidate.

List of abbreviations

BIA+	Bilingual Interactive Activation Plus
EEG	electroencephalography
ERP	event-related potential
LPC	late positivity complex
L1	native language
L2	non-native language
RT	reaction time

Part 1: Introduction

Life is never a neutral experience (Izard 2007). We are always in a positive or a negative mood (i.e. a background affective state), unobtrusively casting a shadow or a glow over our thoughts and behaviour (Forgas 2017). This simple fact of life has found much support in anecdotal and empirical evidence, together showing that a positive and a negative mood exert marked differential effects on different cognitive faculties, such as memory (see Faul and LaBar 2022 for a review), attention (e.g. Irrmischer et al. 2018), social judgements (e.g. Unkelbach et al. 2008), creativity (e.g. Du et al. 2021), decision making (e.g. Vinckier et al. 2018), cognitive control (e.g. Schuch and Koch 2015), and motivation (e.g. Han and Gershoff 2019). Mood has also been found to influence different linguistic domains (see Research article 4, Naranowicz 2022 for a review). For instance, previous research has pointed to facilitative effects of a positive mood on semantic processes (e.g. Chwilla et al. 2011; Van Berkum et al. 2013; Wang et al. 2016), associated with the activation of heuristics-based and assimilative thinking (e.g. Pinheiro et al. 2013). A negative mood, in contrast, has been linked to both facilitatory and inhibitory effects on semantic processes due to the activation of detail-oriented and accommodative thinking (e.g. Vissers et al. 2013).

Little attention has thus far been directed to potential mood effects on language processing in a bilingual context (Kissler and Bromberek-Dyzman 2021). Bilingualism is a ubiquitous phenomenon in the era of mass migration and globalisation. With most people around the world speaking at least two languages, being bilingual or even multilingual is now perceived as a norm (Bialystok 2010; Grosjean 2010). Psycholinguistic research has indicated that bilingualism has profound consequences on our mental architecture (see Kroll et al. 2015 for a review). Strikingly, accumulating evidence has pointed to bilinguals experiencing decreased emotional sensitivity to the non-native language (henceforth L2) compared to the native language (henceforth L1) emotional content (see Pavlenko 2012; Caldwell-Harris 2015; Jończyk 2016 for reviews). Such L2 emotional detachment has been linked to a *foreign language effect* (Keysar et al. 2012): psychological distance experienced when operating in L2, leading among others to reduced heuristic biases in decision-making (Costa et al. 2015), more utilitarian decisions in L2 than L1 (e.g. Cipolletti et al. 2016), and increased honesty in L2 than L1 (Yang et al. 2021). With previous bilingual research concentrating mainly on L1 and L2 emotional content, it remains an open question if and how a bilingual person's current mood influences mechanisms engaged in L1 and L2 processing.

Therefore, the main objective of the present PhD project was to investigate if and how a positive and a negative mood affect language comprehension, based on behavioural and electrophysiological responses in L1 and L2. This research question was addressed in four thematically connected Research articles.

The first part of the present PhD thesis introduces the most relevant theoretical background along with the main research objectives. More detailed descriptions of Research article 1 (Naranowicz et al. 2022a), Research article 2 (Naranowicz et al. 2022b), Research article 3 (Jankowiak et al. 2022) and Research article 4 (Naranowicz 2022) are then provided, justifying the decision-making process leading to their designs.

1.1. Theoretical background

This section introduces definitions key to the present PhD project. Then, the most relevant research on affect and bilingualism, mood and semantic processes as well as mood and bilingualism is briefly introduced.

1.1.1. Defining key concepts

To fully understand how mood affects language processing in bilingual speakers, we should first consider how these terms are conceptualised. *Mood* can be defined as a background affective state that rather unnoticeably changes over time from feeling pleasant (i.e. a positive mood) to unpleasant (i.e. a negative mood; Forgas 2017). In line with the dimensional approach to affect (e.g. Russell 1980), mood is oftentimes perceived as a spectrum, with a highly positive mood and a highly negative mood placed at its ends. Unlike emotion, mood can also be characterised as a low-intensity and diffuse mental state, which changes slowly and is rarely associated with one particular antecedent cause (e.g. Frijda 2009). Note, however, that individual mood-congruent emotional experiences may elicit a discrete mood state, such as frustration, anxiety, or stress (Ekkekakis 2013). Despite its elusive and unobtrusive nature, mood has still been observed to pervasively affect our cognition and behaviour (see Forgas 2017 for a review). Moreover, its adaptational function is to tune cognitive mechanisms, allowing us to adapt mental faculties (e.g. attention, cognitive control, perception, decision-making, etc.) to our subjective experiences (Faul and LaBar 2022). Mood is also strongly influenced by interoception: sensory input from physiological responses or peripheral organs (e.g. it may be changed by hormones or inflammatory states). In short, though it typically escapes our attention, we are always in a mood state, fluctuating on a moment-to-moment basis to help us adapt to our subjective experiences (see also the *Defining affective constructs* section in Research article 4, Naranowicz 2022 for more details).

A *bilingual person* can be broadly defined as an individual using more than one language on a regular basis (Grosjean 2010). Put differently, bilinguals can be characterised as individuals with communicative skills allowing them to interact with speakers of different languages (Butler and Hakuta 2006). While a diverse community of bilingual speakers can be further classified based on many dimensions (see Butler and Hakuta 2006; de Groot 2011 for reviews), the factors critical for this PhD project due to their relationship with affective language include L2 proficiency, dominance as well as the age and context of acquisition. Though early definitions of bilingualism assumed near native-like mastery in both languages (see Dewaele 2015 for a review), bilinguals can be divided into *non-proficient* and *proficient* L2 users to describe those with low and high fluency in L2, respectively. Proficiency is also closely linked to language dominance, with those who mastered L2 at a native-like level being referred to as *balanced*/*non-dominant* bilinguals and those who are still more proficient in their L1 than L2 as *unbalanced*/*dominant* bilinguals. As for the age of acquisition, those bilingual individuals who acquired their L2 in childhood are typically defined as *early* bilinguals and those who started learning their L2 in adolescence or adulthood as *late* bilinguals. In terms of the context of acquisition, bilinguals are typically divided into those who acquired their L2 mainly in *naturalistic* (i.e. through everyday communicative interactions) and *formal* (i.e. through instructional classroom interactions) environments. Note, however, that these binary categories have been adopted by scholars to help them somehow generalise their research findings to bilingual speakers with a given set of characteristics or linguistic backgrounds. In reality, however, each bilingual person develops their own language profile as a result of individual linguistic encounters and history. For this reason, such binary labels should be treated as two opposite ends of one continuum rather than two distinct categories, which would better reflect the complexity of dynamically changing characteristics of bilingual speakers (Butler and Hakuta 2006).

1.1.2. Affect and bilingualism

The present PhD project was to a large extent inspired by previous research on emotional language processing in a bilingual context. While such research has pointed to both similarities and differences between L1 and L2 (see Pavlenko 2012; Caldwell-Harris 2015; Jończyk 2016 for reviews), accumulating evidence has indicated that bilinguals may exhibit decreased sensitivity to emotional (especially negative) content in L2 relative to L1. For instance, self-reported measures have shown that bilinguals experience decreased affective load of swear and taboo words in L2 than L1 (Dewaele 2010). Behavioural evidence has indicated an attenuated Stroop interference effect in L2 relative to L1: decreased accuracy and longer reaction times (henceforth RTs) to emotional words incongruent than congruent with an emotional face, the effect being stronger in L1 than L2 (Fan et al. 2018). Then, physiological research has demonstrated reduced physiological responding (i.e. skin conductance responses) to negative narratives in L2 than L1 in late bilinguals (Jankowiak and Korpal 2018). Electrophysiological measures have also shown reduced N400 amplitudes to negative L2 sentences compared to positive L2 sentences as well as positive and negative L1 sentences (Jończyk et al. 2016). Finally, neuroimaging evidence has pointed to facilitated hemodynamic responses to emotional than neutral narratives in the amygdala as well as the left prefrontal cortex in L1 but not L2 (Hsu et al. 2015). Overall, such reduced L2 emotionality has frequently been associated with learning L2 in a formal environment (e.g. Degner et al. 2012; Dewaele 2010), low L2 proficiency together with late age of L2 acquisition (e.g. Harris et al. 2006), and infrequent use of L2 emotional words (e.g. Degner et al. 2012; Opitz and Degner 2012).

Another significant source of inspiration for the present PhD project was recent research on emotion regulation in a bilingual context (Morawetz et al. 2017; Dylman and Bjärtå 2019; Thoma 2021). For instance, bilinguals have been observed to more effectively down-regulate their negative emotions elicited by aversive pictures in L2 than L1 when performing a task distracting them from their emotions (i.e. implicit emotion regulation; Morawetz et al. 2017). Such decreased emotional responding has been linked to

L2 relative to L1 processing being more cognitively taxing, limiting the cognitive resources available for emotion recognition (Morawetz et al. 2017).

1.1.3. Mood effects on semantic processes

Previous research has demonstrated that a positive and a negative mood may differently exert their influence in numerous linguistic domains (see Research article 4, Naranowicz 2022 for a review), including semantic processing (e.g. Wang et al. 2016), emotional word processing (e.g. Egidi and Nusbaum 2012), syntactic processing (e.g. Jiménez-Ortega et al. 2012), language production (e.g. Out et al. 2020), communicative interactions (e.g. Matovic and Forgas 2018), and reading habits (e.g. Mills et al. 2019). Mood effects on semantic processes have attracted the most attention, though. Behavioural evidence has shown facilitatory effects of a positive mood on spreading activation in semantic memory (e.g. Hänze and Hesse 1993; Bolte et al. 2003), which has been linked to global attentional focus (i.e. greater breadth of attentional selection; Rowe et al. 2006) and reliance on pre-existing knowledge (i.e. heuristics), resulting from greater cognitive ease (Bless et al. 1996). A negative mood, in turn, has been associated with inhibitory effects on spreading activation in semantic memory (Bolte et al. 2003; Storbeck and Clore 2008; Sakaki et al. 2011), related to local attentional focus (i.e. lower breadth of attentional selection; Rowe et al. 2006; Matovic et al. 2014). Similarly, electrophysiological evidence has pointed to facilitated lexico-semantic access (e.g. Federmeier et al. 2001; Pinheiro et al. 2013; Chwilla et al. 2011) as well as semantic integration and re-evaluation (Vissers et al. 2013) in a positive mood, which might be connected to reliance on heuristics and increased motivation (e.g. Vissers et al. 2013). In contrast, a negative mood has been linked to the activation of detail-oriented processing (Pinheiro et al. 2013), suppression of heuristics-based processing (Vissers et al. 2013), decreased associative retrieval from semantic memory (Van Berkum et al. 2013), and higher working memory demands (Vissers et al. 2013).

1.1.4. Mood effects on language processing in bilinguals

Research on mood and language has recently been extended to a bilingual context. Kissler and Bromberek-Dyzman (2021) explored how a positive and a negative mood affect behavioural and electrophysiological responses to emotional words in L1 and L2. To this aim, unbalanced German–English bilinguals watched a positive and a negative mood-inducing film excerpts and made evaluative judgements of single words (i.e. categorised them as positive, negative, or neutral). As for the behavioural measures, they observed that more words were perceived as emotional than neutral in L1, the effect being significantly reduced in L2. Then, they also found a trend towards longer RTs to negative L2 than L1 words, together pointing to increased emotional distance in L2 relative to L1. As for the electrophysiological measures, they observed a mood–language interaction in the N1 time window (i.e. a marker of early lexical access), whereby the N1 was left-lateralised over temporal electrode sites in a positive mood in L1, with no lateralisation effect in a negative mood as well as no mood-driven differences in L2, regardless of word valence. According to Kissler and Bromberek-Dyzman (2021), such results indicate that a current affective state may serve as an early social communicative context for emotional word processing during lexical access (Schindler et al. 2019), which could also account for the observed language-dependent lateralisation effects (Costanzo et al. 2015). Despite such findings, more research is still needed to draw compelling conclusions regarding the relationship between mood and bilingualism.

1.2. Research objectives

Inspired by previous bilingual research on emotional content processing (see Jończyk 2016 for a review), the present PhD project explored if and how a positive and a negative mood (i.e. pleasant and unpleasant background affective states) influence cognitive mechanisms engaged in L1 and L2 comprehension from a behavioural and an electrophysiological perspective. Beyond this general goal, each Research article concentrated on different aspects of L1 and L2 processing to better understand the relationship between mood and bilingualism. Research article 1 (Naranowicz et al. 2022a) concentrated on positive and negative mood effects on emotional language processing in bilinguals from a behavioural perspective, additionally accounting for gender differences. Research article 2

(Naranowicz et al. 2022b) focused on positive and negative mood effects on L1 and L2 processing in bilinguals, zooming in on consecutive stages of language processing. Research article 3 (Jankowiak et al. 2022) concentrated on positive and negative mood effects on creative meaning processing in bilinguals' respective languages. Finally, Research article 4 (Naranowicz 2022) revisited previous theoretical frameworks, methodological issues as well as behavioural and electrophysiological evidence concerning mood effects on semantic processes, additionally situating the experiments reported in the present PhD project in previous literature. Note that individual hypotheses are formulated and discussed in detail in the respective Research articles.

1.3. Research article 1 (Naranowicz et al. 2022a): Mood effects on emotional word processing in bilinguals

Previous research on the relationship between mood and word valence has produced rather inconsistent results, pointing to both mood-congruent (e.g. Ferraro et al. 2003) and mood-incongruent effects (e.g. Sereno et al. 2015). Crucially, recent behavioural and electrophysiological evidence has demonstrated that the relationship between mood and word valence may somewhat be modulated by the language of operation in unbalanced bilinguals (Kissler and Bromberek-Dyzman 2021). This seems to extend previous bilingual research, pointing to emotional detachment (see Jończyk 2016 for a review) and increased implicit emotion regulation (Morawetz et al. 2017) in L2 relative to L1. Strikingly, previous studies have also indicated greater affective expressiveness and sensitivity in females than males (see McCormick et al. 2016 for a review), also observed in the context of mood effects on language comprehension (Federmeier et al. 2001). Thus, what remains unexplored is whether the relationship between mood and the language of operation in the context of emotional word processing could additionally be modulated by gender.

Research article 1 (Naranowicz et al. 2022a) aimed to explore whether and how mood modulates behavioural responses to L1 and L2 emotional words, additionally accounting for potential gender differences. To this end, 56 Polish–English bilinguals (28 females and 28 males) were induced into a positive and a negative mood via the exposure to non-narrative animated film fragments and performed an emotive decision task (i.e. decided if L1 or L2 words were positive, negative, or neutral), while the speed and accuracy of their responses were being recorded. Participants were classified as highly proficient late and unbalanced Polish–English bilinguals, who learnt their L2 (English) in an instructional (i.e. classroom) environment. The linguistic stimuli were 120 Polish (L1) and 120 English (L2) abstract adjectives, including 40 negative (e.g. *lonely, selfish,* and *hideous*), 40 positive (e.g. *awesome, gorgeous,* and *joyful*), and 40 neutral (e.g. *internal, random,* and *multiple*) single words in each language (i.e. there were 40 items per condition). The stimuli were controlled for word frequency, word valence, arousal, concreteness as well as the number of syllables and letters. The mood-inducing stimuli were affectively evocative film fragments of 90 s each, selected based on a separate norming study to elicit a positive (n = 14) and a negative (n = 14) mood. RTs and accuracy were analysed with linear mixed-effects models based on a 2 (language: L1 vs. L2) × 2 (mood: positive vs. negative) × 3 (word valence: positive vs. neutral vs. negative) × 2 (gender: females vs. males) design, with language, mood, and word valence as within-subject variables and gender as a between-subject variable.

While there were no mood-driven effects on response accuracies, the analysis revealed a mood–gender interaction, such that females had faster RTs in the positive compared to the negative mood condition irrespective of the language of operation, with no between-mood differences in RTs in males. Also, females had faster RTs in the positive mood condition than males, with no between-gender differences in RTs in the negative mood condition. Overall, such a temporal advantage in females is consistent with previous research associating a positive mood with facilitated semantic processing, including facilitated spreading activation in semantic memory (e.g. Hänze and Hesse 1993) and facilitated lexico-semantic access (e.g. Pinheiro et al. 2013). Crucially, the presence of such a facilitatory effect only in females suggests that they might be more susceptible to mood changes than males (Federmeier et al. 2001), probably due to increased sensitivity to emotions (Goldstein et al. 2001) or increased physiological reactivity to emotional stimuli (Bianchin and Angrilli 2012) in females than males.

Then, the analysis of RTs also showed an interactive effect of mood, language, and word valence. First, L1 neutral words were responded to faster in the positive mood condition than L2 neutral words, indicating delayed activation of semantic representation in L2 compared to L1 due to a lower subjective frequency of L2 items in unbalanced bilinguals (see the *Bilingual Interactive Activation Plus* model; henceforth *BIA*+; Dijkstra and van Heuven 2002). There were also no differences in RTs to neutral words in the negative mood condition, which points to a potential inhibitory effect of a negative relative to a positive mood on word recognition in L1. Second, both L1 and L2 negative words had faster RTs in the positive than the negative mood condition, indicating that mood did not interact with the recognition of negative words, irrespective of the language of operation. Finally, L2 positive words in the positive mood condition were responded to faster than in the negative mood condition and comparably fast to L1 positive words in both mood conditions. Such a pattern suggests the activation of a cumulative positivity-driven effect, leading to a strong processing advantage for both L1 and L2 words (Pratt and Kelly 2008).

In sum, Research article 1 (Naranowicz et al. 2022a) extended previous research on emotional word processing in a bilingual context by showing that the relationship between word valence and the language of operation may depend upon bilinguals' current affective state (see also Kissler and Bromberek-Dyzman 2021). Another conclusion from this study is that mood may affect language in a gender-dependent manner, with females being more affected behaviourally by a positive mood than males.

Two potential limitations worth addressing in further research emerged here. First, the linguistic material in Research article 1 (Naranowicz et al. 2022a) included single words, which rarely appear in this form in real life. Indeed, our communicative interactions are based on broadly construed contexts rather than decontextualised linguistic units (see Jończyk 2016 for a review). Therefore, to improve the ecological validity of research on mood–language interactions, further research could benefit greatly from adopting a more pragmatic perspective, employing the linguistic stimuli embedded in broader semantic contexts (e.g. sentences). Second, the study design employed in Research article 1 (Naranowicz et al. 2022a) was fairly complex, making the interpretation of the observed results challenging. Therefore, before delving into a complex relationship between mood and emotional words further, future research should concentrate on affectively neutral language, the results of which could also serve as a baseline for later investigations of emotional language. Critically, note that employing neutral rather than emotional language would also benefit from a change of focus from abstract to concrete items. Abstract words are typically more emotionally charged than neutral words (Kousta et al. 2011). Such an abstractness–emotionality interaction might be explained by the embodied views on semantic representations (e.g. Kousta et al. 2011; Ferré et al. 2017), whereby affective information is central to the representation of abstract words and sensory-motor information to the representation of concrete words. Arguably, concrete words may also be more suitable for studying semantic processes in sentential contexts than abstract words, as they have been associated with increased activation of semantically related concepts due to higher involvement of mental imagery (Kanske and Kotz 2007).

The behavioural results reported in Research 1 (Naranowicz et al. 2022a) also give reasonable grounds for further exploration of mood effects on the mechanisms engaged in language comprehension in real time. Admittedly, behavioural measures, such as RTs and accuracy rates, reflect the end product of the whole meaning-driven decision-making process (Liu 2021), not offering insights into online semantic processes. Therefore, future research focusing on mood–language interactions could employ electroencephalography (EEG), which offers a continuous measure of brain activity during language processing with a millisecond precision (Luck 2014). All in all, the identified limitations (i.e. employing decontextualised linguistic stimuli and a complex research design) as well as the benefits of electrophysiological measures laid the foundations for Research article 2 (Naranowicz et al. 2022b).

1.4. Research article 2 (Naranowicz et al. 2022b): Mood effects on consecutive stages of language processing in bilinguals

Growing behavioural and electrophysiological research has indicated that a positive and a negative mood may differently influence semantic processes, typically pointing to facilitatory effects of a positive mood on meaning comprehension (see Research article 4, Naranowicz 2022 for a review). Such research has recently been extended to a bilingual context, showing that mood may interact with the language of operation in the context of emotional word processing in unbalanced bilinguals (Kissler and Bromberek-Dyzman 2021; Research article 1, Naranowicz et al. 2022a). However, previous work has been limited to studying mood effects on decontextualised words, and still not much is known about whether mood affects semantic processing differently in L1 and L2 in broader communicative (e.g. sentential) contexts.

Research article 2 (Naranowicz et al. 2022b) aimed to investigate whether and how mood alters language processing in unbalanced bilinguals from an electrophysiological perspective, taking into account consecutive stages of visual word processing. To this end, 22 Polish–English bilinguals were induced into a positive and a negative mood via the exposure to animated film fragments and performed a semantic decision task (i.e. decided if L1 or L2 neutral sentences were meaningful or meaningless) while their behavioural and electrophysiological responses were being recorded. Participants had comparable linguistic profiles to those in Research article 1 (Naranowicz et al. 2022a; i.e. highly proficient late unbalanced Polish–English bilinguals who acquired their L2 in a formal context) and were induced into a positive and a negative mood also with the same mood-inducing materials adopted from Research article 1 (Naranowicz et al. 2022a; i.e. 28 animated non-narrative film fragments). The linguistic stimuli were 90 Polish (L1) and 90 English (L2) neutral concrete nouns, each embedded in both semantically congruent (i.e. meaningful and highly expected) and incongruent (i.e. meaningless and rather unexpected) sentence frames (e.g. *These houses were transformed into country mansions/lobsters permanently.*, respectively). In total, there were 180 Polish (L1) and 180 English (L2) individual sentences, presented along with 60 filler sentences in each language (n_{Total} = 480 sentences; 45 items per condition). Similarly to the adjectives employed in Research article 1 (Naranowicz et al. 2022a), the nouns were controlled for word frequency, word valence, arousal, concreteness as well as the number of syllables and letters. Based on the results of a separate norming study, the constructed sentences were matched in terms of meaningfulness, probability of use in everyday language, and valence. To tap into individual consecutive stages of visual word processing, five event-related potential (henceforth ERP) components were analysed: the P1 (i.e. as a marker of pre-lexical perceptual processing), the N1 (i.e. as a marker of lexical processing), the N2 and the N400 (i.e. as markers of lexico-semantic processing), and the late positivity complex (henceforth LPC; i.e. as a marker of semantic integration and re-evaluation). Mean ERP amplitudes were analysed based on a 2 (language: L1 vs. L2) × 2 (mood: positive vs. negative) × 2 (sentence type: meaningful vs. meaningless) within-subject design, with additional electrode position (anterior vs. central vs. posterior) and laterality (left-lateral vs. medial vs. right-handed) variables for the N400 and LPC components.

The analyses revealed a general mood effect at the pre-lexical stage along with mood–language interactions at the lexical and early lexico-semantic processing stages. In the P1 time window (70–130 ms), the analysis showed higher P1 amplitudes in the positive compared to the negative mood condition, suggesting that a positive mood triggers a greater breadth of attentional focus (i.e. a global attentional focus) than a negative mood (see Moriya and Nittono 2011 for a review). Then, in the N1 time frame (170–230 ms), the analysis revealed smaller N1 amplitudes in the negative relative to the positive mood condition in L2, with no between-mood differences in L1. Interestingly, such an ERP pattern was then mirrored in the N2 time window (250–350 ms), where the analysis showed decreased N2 amplitudes in the negative relative to the positive mood condition in L1, with no between-mood differences in L2. Decreased amplitudes in the negative relative to the positive mood conditions point to the activation of a more analytical (i.e. detail-oriented) processing (e.g. Vissers et al. 2013) due to increased cognitive demands in L2 during the lexical processing stage and in L1 during the early lexico-semantic processing stage.

Then, the analyses also showed mood–language interactive effects at the lexico-semantic and late semantic processing stages. In the N400 time frame (300–500 ms), in the positive mood condition, the analysis showed that L2 meaningless relative to meaningful sentences elicited increased N400 amplitudes, with no between–sentence type differences in L1. In contrast, in the negative mood condition, the analysis revealed increased N400 responses to meaningless relative to meaningful sentences, irrespective of the language of operation. Such results indicate a facilitatory effect of a positive mood on lexico-semantic processing (e.g. Federmeier et al. 2001; Pinheiro et al. 2013; Wang et al. 2016). Yet, this beneficial effect was limited to L1, which suggests that the mechanisms related to L2 lexico-semantic access may not be affected by mood changes to the same degree as in L1. This is consistent with recent research pointing to increased implicit emotion regulation in L2 than L1 due to higher cognitive engagement (Morawetz et al. 2017). In the LPC time window (600–800 ms), in the negative mood condition, the analysis revealed that meaningful sentences evoked higher LPC amplitudes in L2 than L1, with no between–language differences for meaningless sentences. In contrast, in the positive mood condition, the analysis showed increased LPC amplitudes for meaningless compared to meaningful sentences, irrespective of the language of operation. These results suggest that a negative mood led to the suppression of full semantic integration in L2 only, possibly as a preventive mechanism against the likely deleterious effects of a negative mood (Wu and Thierry 2012; Jończyk et al. 2016).

To summarise, Research article 2 (Naranowicz et al. 2022b) revealed that a positive and a negative mood may differently affect consecutive stages of language processing in unbalanced bilinguals in a language-dependent manner. First, a positive mood may lead to a wide attentional focus at a perceptual (i.e. pre-lexical) processing stage. Second, a negative mood may trigger analytical processing in L2 only at a lexical processing stage and in L1 only at an early lexico-semantic processing stage. Third, a positive mood may facilitate meaning retrieval from semantic memory in L1 only at a lexico-semantic processing stage. Finally, a negative mood may inhibit full semantic integration of L2 only at a late semantic processing stage.

As confirmed by the norming study, the sentences employed in Research article 2 (Naranowicz et al. 2022b) were either unequivocally meaningful or meaningless. It seems that, consequently, the meaningfulness judgements were not particularly challenging for participants, as indexed by very high accuracy rates ($M_{Accuracy}$ = 96.65%) along with a sizable N400 effect (i.e. the difference in N400 amplitudes elicited by meaningful and meaningless sentences). Yet, not all messages in our everyday communicative interactions are so transparent. So, it remains an open question whether and how a positive and a negative mood influence the processing of semantically complex messages, such as those expressed via highly creative, metaphorical language. This gap in research gave rise to Research article 3 (Jankowiak et al. 2022).

1.5. Research article 3 (Jankowiak et al. 2022): Mood effects on creative meaning processing in bilinguals

Previous research has demonstrated that a positive and a negative mood may to some extent lead to differential effects on L1 and L2 processing, the effects being restricted to emotional words (Kissler and Bromberek-Dyzman 2021; Research article 1, Naranowicz et al. 2022a) and semantically unambiguous sentential contexts (Research article 2; Naranowicz et al. 2022b). Little is known, however, about mood effects on complex meanings, such as creative metaphorical messages. Creative meaning processing can, among others, be explored through electrophysiological responses to novel metaphors – unfamiliar and highly creative meanings, requiring the activation of extended cross-domain mapping mechanisms that involve recognition of characteristics common to two individual concepts, consequently enabling novel meaning creation (e.g. Gibbs and Colston 2012). Recently, mechanisms engaged in the processing of novel metaphors have also been investigated from a bilingual perspective, suggesting that while lexico-semantic access may be more cognitively taxing in L2 than L1, comparable cognitive resources might be invested in semantic integration of L1 and L2 during novel meaning processing (Jankowiak et al. 2021). Yet, what is still largely unexplored in the context of L1 and L2 processing is whether and how mood modulates creative meaning processing, which may consequently help us understand the relationship between mood and the processing of semantically complex messages.

Research article 3 (Jankowiak et al. 2022) aimed to examine whether and how mood affects creative meaning processing in unbalanced bilinguals from an electrophysiological perspective. Similarly to Research article 2 (Naranowicz et al. 2022b), 47 Polish–English bilinguals were put experimentally into a positive and a negative mood with animated film fragments and performed a semantic decision task (i.e. decided if L1 or L2 neutral sentences were meaningful or meaningless) while their electrophysiological activity was being recorded. Participants were randomly assigned either to the L1 block (n = 24) or to the L2 block (n = 23). To ensure the comparability with Research article 1 (Naranowicz et al. 2022a) and Research article 2 (Naranowicz et al. 2022b), participants were classified as highly proficient late unbalanced Polish–English bilinguals who acquired their L2 (English) in a formal context, and the mood-inducing materials were again adopted from Research article 1 (Naranowicz et al. 2022a; i.e. 28 animated non-narrative film fragments). The linguistic stimuli were adapted from a database by Jankowiak (2020). They included 180 Polish (L1) and 180 English (L2) sentences divided into three sentence types: 60 literal sentences (i.e. meaningful sentences; e.g. *This piece of furniture is a drawer filled with socks.*), 60 novel metaphors (i.e. meaningful sentences; e.g. *My heart is a drawer for secret feelings.*), and anomalous sentences (i.e. meaningless sentences; e.g. *A bug is a drawer shut with a bang.*) in each language. There were also 60 filler sentences in each language (n_{Total} = 480 sentences; 60 items per condition). The critical nouns were controlled for word frequency, word valence, arousal, concreteness as well as the number of syllables and letters. The sentences were matched in terms of meaningfulness, familiarity, and metaphoricity. Crucially, unlike Research article 2 (Naranowicz et al. 2022b), the semantic anomalies were based on general world knowledge violations. Mean N400 and LPC amplitudes were analysed based on a 2 (language: L1 vs. L2) × 2 (mood: positive vs. negative) × 3 (sentence type: literal vs. novel metaphoric vs. anomalous) design, with mood and sentence type being within-subject variables and language being a between-subject variable.

In the N400 time frame (300–500 ms), the analysis revealed only larger N400 responses to both novel metaphoric and literal than anomalous sentences, suggesting that the mechanisms engaged in the processing of novel metaphoric meaning were more cognitively taxing than those engaged in literal meaning processing (Arzouan et al. 2007; Lai et al. 2009). Then, in the LPC time window (600–800 ms), the analysis showed larger

LPC responses to anomalous than both literal and novel metaphoric sentences in the positive mood condition, indicating that the creative meaning of novel metaphors was eventually effectively integrated at the stage of meaning re-evaluation (De Grauwe et al. 2010). In contrast, the LPC responses to all three sentence types were comparable in the negative mood condition. Together, these results suggest that the semantic anomalies built on general knowledge violations might be re-evaluated to a greater extent in a positive relative to a negative mood due to the activation of heuristics-based and assimilative processing in a positive mood, which may be suppressed in a negative mood (Vissers et al. 2013).

In sum, Research article 3 (Jankowiak et al. 2022) did not point to mood-dependent processing of highly creative novel metaphoric messages. Instead, it revealed that while novel metaphors are initially processed as meaningless sentences at a lexico-semantic processing stage, they became fully meaningful at a semantic re-evaluation stage, irrespective of the language of operation as well as the mood type. Crucially, however, Research article 3 (Jankowiak et al. 2022) revealed an interesting mood-dependent processing pattern for semantic anomalies, such that a positive mood may promote and a negative mood impede heuristics-based processing of general knowledge violations during semantic integration, irrespective of the language of operation.

1.6. Research article 4 (Naranowicz 2022): Mood effects on semantic processing revisited

Research article 4 (Naranowicz 2022) aimed to systematically revisit previous behavioural and electrophysiological research on the relationship between mood and semantic processes. A secondary goal was also to situate Research article 1 (Naranowicz et al. 2022a), Research article 2 (Naranowicz et al. 2022b), and Research article 3 (Jankowiak et al. 2022) in previous theoretical and methodological frameworks as well as empirical research.

A review of the theoretical frameworks for mood effects on cognitive mechanisms indicated that mood has been predicted to exert marked effects on four cognitive faculties – perception (e.g. Bless 2001), attention (e.g. Schwarz and Clore 1983), motivation (e.g. Schwarz 2002), and exploration tendencies (e.g. Zadra and Clore 2011). Previous research on mood–semantic processes interactions (e.g. Bless et al. 1996; Vissers et al.

2013; Van Berkum et al. 2013) has mostly been consistent with the perception-oriented accounts (e.g. Bless 2001; Bless and Fiedler 2006; Schwarz and Clore 1983). Strikingly, the review also revealed that the *State of Mind* framework (Herz et al. 2020) – a recent and seemingly comprehensive proposal delineating complex relations between mood, thinking, perception, attention, and openness to experience – proposed a contradictory view on perceptual mechanisms relative to the revised empirical evidence. Specifically, Herz et al. (2020) proposed that reliance on sensory information can be associated with bottom-up processing and, consequently, a positive mood, whereas reliance on predictions with top-down processing and a negative mood.

A review of the methodological approaches to studying mood effects on semantic processes has pointed to the greatest affective potency of audio-visual materials in eliciting a positive and a negative mood (see Joseph et al. 2020 for a review), whose effects may additionally be reinforced by numerous procedural practices (e.g. instructing participants to put themselves into a targeted mood state; Rottenberg et al. 2018). The review also discussed potential benefits of measuring mood changes with a broader spectrum of mood measurements (e.g. employing unipolar and bipolar scales), ethical considerations in experimental mood manipulation, and potential measurement errors (e.g. a social desirability bias or demand characteristics; Gray and Watson 2007).

A review of previous behavioural and electrophysiological research on mood and semantic processes revealed a rather consistent picture, pointing to mood-dependent cognitive strategies that affect semantic processes. A positive mood has been associated with heuristics-based assimilative processing (Van Berkum et al. 2013) and overall facilitated semantic processing (e.g. Federmeier et al. 2001), whereas a negative mood with analytical and accommodative processing (e.g. Vissers et al. 2013) and sometimes impeded semantic processing (e.g. Liu 2021). However, the review also helped identify several discrepancies in the observed findings. First, both behavioural (Hänze and Hesse 1993 vs. Bolte et al. 2003) and electrophysiological (Federmeier et al. 2001 vs. Pinheiro et al. 2013) research has inconsistently demonstrated that a positive mood may facilitate the activation of either closely or weakly associated concepts in semantic memory. Second, previous electrophysiological research has produced rather inconsistent results regarding N400 modulation by mood (e.g. Pinheiro et al. 2013 vs. Ogawa and Nittono 2019). Third, researchers have employed different paradigms to explore mood effects on attentional focus, leading to some incompatible findings (e.g. Sakaki et al. 2011 vs. Rowe et al. 2006). Fourth, it also remains unresolved whether a negative mood may sensitise us to contextual information, that is, whether a negative mood triggers selective attention and, consequently, context-specific predictions (e.g. Pinheiro et al. 2013 vs. Wang et al. 2016). Furthermore, Research article 4 (Naranowicz 2022) also highlighted the importance of employing a replication-oriented approach (Shrout and Rodgers 2018) as well as focusing on gender differences (Federmeier et al. 2001; Research article 1, Naranowicz et al. 2022a) and practical implications in future research.

Part 2: General discussion

The second part of the present PhD thesis provides a general discussion of the selected critical findings from Research article 1 (Naranowicz et al. 2022a), Research article 2 (Naranowicz et al. 2022b), and Research article 3 (Jankowiak et al. 2022). The obtained self-reported (i.e. mood ratings), behavioural (i.e. response speed and accuracy), and electrophysiological (i.e. ERPs) results are evaluated comparatively across studies. Additionally, ethical considerations, limitations, and future research directions are also considered. Some behavioural results that were not reported in the respective Research articles are discussed here as well. Note that all individual results are discussed in detail with reference to the formulated hypotheses in the respective Research articles.

2.1. Self-reported data: Mood ratings

In all three experimental studies reported in the present PhD project, participants provided mood ratings before (i.e. a baseline measure) and after each experiment/mood block, using mood valence and arousal scales as well as the *Positive and Negative Affect Schedule* (PANAS) questionnaire (Watson et al. 1988; as translated into Polish by Fajkowska and Marszał-Wiśniewska 2009). In Research article 1 (Naranowicz et al. 2022a) and Research article 2 (Naranowicz et al. 2022b), the analysis of the mood valence and PANAS ratings pointed to participants experiencing an increase in mood in the positive mood condition along with a decrease in the negative mood condition after the experiment relative to the baseline measure. In Research article 3 (Jankowiak et al. 2022), in contrast, participants reported a decrease in mood in the negative mood condition, with no difference in mood ratings in the positive mood condition after the mood block relative to the baseline measure. Note, however, that although positive mood induction in Research article 3 (Jankowiak et al. 2022) was observably less effective than in the two earlier studies, participants' mood ratings indicated that they maintained a comparably positive affective state in the positive mood condition. Therefore, it can be assumed that in all three experiments participants were in the targeted mood states while performing the respective tasks. Moreover, participants reported feeling more physiologically aroused after the experiment/each mood block relative to the baseline measure, irrespective of language and mood type, minimising the chances of the observed mood effects on linguistic processes being differently driven by the intensity of experienced affective states (Joseph et al. 2020).

There are at least two potential causes of the observed lack of increase in mood ratings in the positive mood condition in Research article 3 (Jankowiak et al. 2022). First, the presence of novel metaphors among the experimental stimuli increased the complexity of the task at hand – participants were more likely to employ complex processing strategies, intensely searching for a potential figurative meaning in all three sentence types (Jankowiak et al. 2017; Jankowiak et al. 2022). This might therefore evince that the strength of positive mood induction may decrease proportionally to increased task demands. Besides fatigue, increased cognitive demands could also elicit irritation, additionally impairing the effectiveness of positive mood induction. Second, unlike in the two remaining studies, participants in Research article 3 (Jankowiak et al. 2022) were induced into both a positive and a negative mood during one experimental session, with the two mood blocks being presented in a counterbalanced order and separated by a 10-minute low-arousing documentary whose aim was to "neutralise" the mood state induced in the first mood block. This suggests that participants may be less susceptible to positive mood elicitation when being previously exposed to intensely negative content.

2.2. Behavioural data: Response speed and accuracy

In Research article 1 (Naranowicz et al. 2022a), the behavioural data reflected the speed and accuracy of evaluative judgements on word valence (i.e. whether a presented word was positive, negative, or neutral). In Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022)[1], the behavioural data included the speed and accuracy of meaningfulness judgements (i.e., whether a presented sentence was meaningful or meaningless) on different sentence types: meaningful and meaningless sentences in Research article 2 (Naranowicz et al. 2022b) as well as meaningful (i.e. literal), meaningless (i.e. anomalous), and novel metaphoric sentences in Research article 3 (Jankowiak

[1]Note that the analyses of response accuracies in Research article 3 (Jankowiak et al. 2022) are not reported in the published text. Instead, they are provided in Supplementary materials, as recommended by one of the reviewers, at https://osf.io/uksm3/.

et al. 2022). Note, however, that the RT data in these two electrophysiological experiments were uninformative (and consequently not included in the analyses) due to the presentation of critical words in a mid-sentence position. That is, while participants made the meaningfulness judgements in the middle of the stimulus stream, their responses were delayed until the end of it, cancelling any meaningful modulations of RTs.

The analysis of the behavioural data obtained in Research article 1 (Naranowicz et al. 2022a) revealed a novel finding, pointing towards a positivity superiority effect on evaluative judgements that minimised the between-language differences in word recognition speed. A positive mood led to the disappearance of a frequently reported temporal difference between L1 and L2 (e.g. Dijkstra and van Heuven 2002), the effect being restricted to positive words. Such a mood-congruency effect may be linked to the activation of a positivity-driven assimilative mechanism in semantic memory, as reflected in the facilitated speed of word recognition in both L1 and L2. Specifically, positive compared to negative content has been argued to be encoded in a highly assimilative manner, leading to more efficient retrieval of positive than negative and neutral information from semantic memory (i.e. a memory bias; see Faul and LaBar 2022 for a review). This is also consistent with the *positivity bias* account (e.g. Ito and Cacioppo 2005), whereby positive words are better interconnected in semantic memory compared to negative and neutral words, thus leading to preferential processing of positive content (see Kauschke et al. 2019 for a review). Similarly, a positive mood has frequently been reported to promote assimilative (i.e. top-down and relational) thinking, increasing reliance on the stored knowledge (see Research paper 4, Naranowicz 2022 for a review). Therefore, it can be argued that a positive mood serves as an associative cue for positive content in semantic memory, facilitating meaning retrieval irrespective of the language of operation.

The behavioural results from Research article 1 (Naranowicz et al. 2022a) also extended our understanding of affect–gender interactions and their consequences for word recognition. While male participants remained behaviourally unaffected by mood fluctuations, female participants overall responded to words faster in a positive than a negative mood, irrespective of word valence and the language of operation. Overall, the facilitatory effect of a positive relative to a negative mood in females accords with previous research pointing to facilitatory effects of a positive mood on language comprehension (e.g. Chwilla et al. 2011; Vissers et al. 2013; Wang et al. 2016; see Research article 4, Naranowicz 2022 for a review). The observed gender differences are consistent with accumulating evidence that indicates females' increased sensitivity to affective stimuli and emotions (e.g. Codispoti et al. 2008; Bianchin and Angrilli 2012), also in the context of language comprehension (Federmeier et al. 2001; see Research article 1, Naranowicz et al. 2022a for a detailed discussion).

Another key finding from the behavioural data reported in both Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022) indicated that a facilitatory effect of a positive mood on the accuracy of meaningfulness judgements may occur when task demands are optimally challenging. First, in both experiments, meaningfulness judgements on semantic anomalies seemed to have been the least challenging of all sentence types and thus remained unaffected by mood changes: the responses to the semantic anomalies were the most accurate of all sentence types, irrespectively of mood and the language of operation. Such a recognition advantage for meaningless sentences was unsurprising, as the semantic anomalies in both experiments were carefully constructed to unambiguously violate predictability and/or logic. Analogously, making judgements about meaningful (i.e. literal) relative to meaningless (i.e. anomalous) sentences could have been more challenging for participants due to the absence of an aberrant word explicitly violating semantic congruency. For this reason, meaningful sentences were overall responded to with lower accuracy than meaningless sentences in both experiments, in line with previous behavioural evidence (e.g. Van Dyke and McElree 2007). Interestingly, however, this frequently reported recognition advantage of meaningless over meaningful sentences disappeared in a positive mood in Research article 2 (Naranowicz et al. 2022b). Similarly, in Research article 3 (Jankowiak et al. 2022), the recognition of meaningful (i.e. literal) sentences was facilitated in a positive relative to a negative mood. Arguably, such facilitatory effects on literal meanings suggest that a positive mood may sensitise us to the most relevant contextual information (e.g. Wang et al. 2016; cf. Pinheiro et al. 2013), which might have translated into heightened accuracy of meaningfulness judgements. Finally, a beneficial effect of a positive relative to a negative mood was also observed for novel metaphors (i.e. the most perplexing sentence condition) in Research article 3 (Jankowiak et al. 2022), yet only in L1. Novel metaphors represent creative and semantically complex meanings, whose processing might be particularly difficult in L2 relative to L1 (Jankowiak et al. 2017; Jankowiak et al. 2021). This suggests that the strength of the facilitatory effect of a positive mood on meaningfulness judgements may weaken when a semantic task is too challenging.

The behavioural data reported in Research article 3 (Jankowiak et al. 2022) also provided a deeper insight into the relationship between mood and creative language comprehension in a bilingual context. The observed facilitatory effect of a positive relative to a negative mood on novel metaphoric sentences in L1 but not L2 was in fact the only finding in Research article 3 (Jankowiak et al. 2022) indicating that mood interacts with creative meaning comprehension in a language-dependent manner. The reported behavioural and electrophysiological patterns (see Research article 3, Jankowiak et al. 2022 for details) together demonstrated that while mood may not exert any marked effects on online novel meaning processing in either L1 or L2 (see Research article 3, Jankowiak et al. 2022 for details), a positive relative to a negative mood may still increase sensitivity to figurative meaning in L1 at a behavioural level, still leaving L2 unaffected by mood fluctuations. As novel metaphor comprehension requires the engagement of resource-intensive meaning-creation processes (Jankowiak et al. 2021), making semantic judgements about novel meanings in a foreign language (L2) is likely to be too cognitively taxing for a positive mood effect to occur. Such an interpretation is also consistent with research on emotion regulation in a bilingual context, pointing to decreased emotional responding in L2 relative to L1 due to the involvement of the cognitive resources available for emotion recognition in L2 processing (Morawetz et al. 2017). Additionally, this interpretation may also contribute to our understanding of the interactions between mood and semantic complexity, suggesting that the strength of positive mood effects on language comprehension may decrease proportionally to increasing semantic complexity.

Additionally, the analyses of the behavioural data obtained in all three experiments revealed fixed effects of word types and sentence types, the occurrence of which points to the replicability of frequently reported behavioural results. In Research article 1 (Naranowicz et al. 2022a), participants made more accurate evaluative judgements about positive and negative than neutral words. Moreover, positive words were responded to the fastest, followed by negative words, and finally neutral words. The observed processing facilitation of emotional relative to neutral stimuli accords with many behavioural studies (e.g. Yap and Seow 2014; Vinson et al. 2014; see Jończyk 2016 for a review), and is frequently discussed in the context of the motivated attention account (e.g. Cacioppo et al. 1999). Namely, affective relative to neutral information is argued to have higher motivational relevance, with positive and negative stimuli respectively eliciting appetitive and defensive reactions, which together promote survival-oriented behaviours (Lang et al. 1993). Then, in Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022), participants made more accurate judgements about meaningless than meaningful sentences. Such results are consistent with many previous studies on sentence comprehension (e.g. Van Dyke and McElree 2007; Weber and Lavric 2008; Jankowiak et al. 2017) and are rather unsurprising given that semantic anomalies are typically carefully created so as to unambiguously violate semantic congruency, which was also the case in both studies reported here.

The analyses also showed behavioural patterns typically observed in bilingual research. In Research article 1 (Naranowicz et al. 2022a), while participants made equally accurate evaluative judgments on L1 and L2 words, L1 words were responded to significantly faster than L2 words. Then, participants made more accurate meaningfulness judgements on L1 than L2 sentences in Research article 2 (Naranowicz et al. 2022b). Comparable results have frequently been reported in previous research on semantic processing (see Jiang 2012 for a review). They are also consistent with the temporal delay assumption of the *BIA+* model (Dijkstra and van Heuven 2002), whereby the activation of L2 relative to L1 representations in semantic memory is delayed and less automatic in unbalanced bilinguals, who are typically less frequently exposed to L2 than L1 words. Surprisingly, however, there was no between-language difference observed in response accuracy in Research article 3 (Jankowiak et al. 2022). Such inconsistency might be explained by the presence of novel metaphors among the experimental stimuli, especially given that this is the main methodological difference between Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022). Processing creative language may entail more complex strategies, making participants search for a potential meaning more intensively and increasing cognitive demands irrespective of the language of operation (Jankowiak et al. 2017; Jankowiak et al. 2021). This also seems to be reflected in overall high N400 amplitudes in Research article 3 (Jankowiak et al. 2022), irrespective of the sentence type.

2.3. Electrophysiological data: Event-related potentials

The analyses of the electrophysiological responses in Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022) concentrated primarily on two ERP components: the N400 indexing lexico-semantic processing (Kutas and Hillyard 1984) as well as the LPC indexing semantic integration and re-analysis (Friedman and Johnson 2000; see also the *Electrophysiological evidence* section in Research article 4, Naranowicz 2022 for details). In both studies, the two components were analysed over frontocentral (FC1, FCz, FC2), central (C1, Cz, C2), and centroparietal (CP1, CPz, CP2) electrodes in the 300–500 ms (N400) and 600–800 ms (LPC) time frames.

Overall, Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022) together offered valuable insights into the relationship between affect and bilingual language processing. Unexpectedly, the two electrophysiological studies revealed different mood effects on lexico-semantic processing as well as semantic integration and re-evaluation. First, Research article 2 (Naranowicz et al. 2022b) revealed a language-dependent facilitatory effect of a positive mood on lexico-semantic processing, as indexed by a significant reduction of a frequently reported N400 meaningfulness effect (i.e. a larger N400 response to meaningless than meaningful sentences) in the positive mood condition in L1 but not L2. Such a result is consistent with previous electrophysiological evidence suggesting that a positive mood is associated with facilitated lexico-semantic processing in L1 due to the allocation of attentional resources to the most relevant contextual information and the activation of an assimilative thinking style (e.g. Wang et al. 2016). Crucially, this result also extended previous monolingual research to a bilingual context by demonstrating that lexico-semantic processing in L2 may be "immune" to mood changes in an L2 context, likely due to the activation of increased emotion regulation strategies in L2 than L1 (e.g. Morawetz et al. 2017). There was also a language-dependent inhibitory effect of a negative mood on semantic integration and re-analysis, as indexed by an increased LPC response to L2 than L1 meaningful sentences. Such suppression of full semantic integration in L2 relative to L1 may be indicative of the activation of preventive mechanisms against likely deleterious effects of a negative mood in an L2 context (Wu and Thierry 2012; Jończyk et al. 2016). Alternatively, increased semantic re-evaluation of L2 sentences may also be indicative of high cognitive demands triggered by both L2 comprehension and being in a negative mood. Namely, consistently with the theoretical accounts highlighting the motivational and adaptive functions of mood (e.g. Schwarz 2002), a negative mood may promote vigilant and effortful thinking (see Research article 4, Naranowicz 2022 for a review). Also, participants comprehended sentences in their foreign language (L2), which is also more cognitively taxing than L1 comprehension.

In contrast, Research article 3 (Jankowiak et al. 2022) did not reveal any mood-driven N400 modulations. There was a language-independent effect on semantic integration and re-analysis in a positive mood, as indexed by a classic LPC meaningfulness effect in both L1 and L2, which was significantly reduced in a negative mood where all three sentence types converged in both languages. Such results accord well with those observed by Vissers et al. (2013), which also explains the differences in the observed mood effects between Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022). Specifically, while the sentences in Research article 2 (Naranowicz et al. 2022b) were built based on semantic expectedness (i.e. the semantic anomalies were rather unexpected yet not completely nonsensical; e.g. *These houses were transformed into country lobsters…*), those in Research article 3 (Jankowiak et al. 2022) were built on general knowledge violations (i.e. the semantic anomalies that defy logic; e.g. *A bug is a drawer…*). Together, the observed lack of a mood effect in the N400 time window followed by a mood-driven effect in the LPC time window suggest that semantically anomalous information is re-evaluated to a greater extent in a positive mood due to the activation of heuristics-based, assimilative processing, which is suppressed in a negative mood leading to rather superficial semantic integration (Vissers et al. 2013). Such a conclusion is also consistent with the *Mood and general knowledge* (Schwarz and Clore 1983) as well as *Affect-as-information* hypotheses (Schwarz and Clore 1983; Clore et al. 2001; Clore and Storbeck 2006), whereby the reliance on heuristics in a positive mood might be triggered by being in a benign situation and effortless information processing. By analogy, the suppression of heuristics-based thinking in a negative mood might be associated with eminent threat and the activation of increased survival-driven mechanisms, consequently leading to detail-oriented processing (see the *Theoretical considerations* section in Research paper 4, Naranowicz 2022 for details).

Beyond the key question of how mood affects semantic processes, the electrophysiological studies reported in the present PhD project also deepened our understanding of how mood affects pre-semantic stages of bilingual language processing. While there were no early ERP modulations observed in Research article 3 (Jankowiak et al. 2022), Research article 2 (Naranowicz et al. 2022b) revealed differential mood effects on early electrophysiological responses, as indexed by mood-driven amplitude changes in the P1 (i.e. a marker of pre-lexical, perceptual processing), N1 (i.e. a marker of lexical access), and N2 (i.e. a marker of early lexico-semantic processing) time windows (see Research article 2, Naranowicz et al. 2022b for detailed discussion). Given that these ERP components are sensitive to perceptual and lexical characteristics of words, the lack of early electrophysiological modulations in Research article 3 (Jankowiak et al. 2022) might be related to repeated use of the same critical word in all three sentence conditions. Specifically, being exposed to the same lexical item in close temporal proximity could lead to a priming effect and, consequently, an automatic recognition and facilitated lexical access in both languages and mood conditions.

Additionally, in both Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022), the analyses of the electrophysiological data also revealed broadly distributed, language-independent effects of sentence types, such that meaningless sentences elicited larger N400 and LPC mean amplitudes than meaningful sentences in both L1 and L2. These ERP patterns point to meaningless content requiring increased cognitive engagement for lexico-semantic access, semantic integration and re-evaluation than meaningful content (see the *Electrophysiological evidence* section in Research article 4, Naranowicz 2022 for a review). Similarly to the reported behavioural data, such findings point to the replicability of the observed effects. Moreover, in Research article 3 (Jankowiak et al. 2022), novel metaphors converged with meaningless (i.e. anomalous) sentences and elicited larger amplitudes than meaningful (i.e. literal) sentences in the N400 time window. In contrast, novel metaphors converged with meaningful (i.e. literal) sentences and elicited smaller amplitudes than meaningless (i.e. anomalous) sentences in the LPC time window. These results suggest that while the comprehension of novel meaning is initially cognitively taxing at the lexico-semantic processing stage (e.g. Lai et al. 2009), it is eventually facilitated at the semantic integration and re-evaluation stage (e.g. De Grauwe et al. 2010).

2.4. Ethical challenges

In the present PhD project, all experiments were conducted in accordance with the Declaration of Helsinki. Crucially, they were also first approved by the Ethics Committee for Research Involving Human Participants at Adam Mickiewicz University, Poznań: Research article 1 (Naranowicz et al. 2022a) – Resolution № 28/2018/2019 approved on 3 June 2019 (see Appendix I); (ii) Research article 2 (Naranowicz et al. 2022b) – Resolution № 34/2019/2020 approved on 3 February 2020 (see Appendix J); (iii) Research article 3 (Jankowiak et al. 2022) – Resolution № 1/2020/2021 approved on 8 February 2021 (see Appendix K).

The greatest ethical challenge in all experiments conducted within the present PhD project was mood manipulation. Careful attention was devoted to selecting mood-inducing stimuli powerful enough to alter participants' behavioural and electrophysiological responses. In addition to increased L2-related cognitive demands (e.g. Iacozza et al. 2017), participants were faced with an emotionally and mentally intense situation, continuously experiencing and regulating rather intense positive and negative emotions. Therefore, special attention was directed to pre-screening procedures, helping to qualify for participation only the individuals who could potentially cope with such intense exposure to emotionally evocative content, especially in the negative mood condition. In all experiments, participants were openly informed about the significantly emotional character of the presented video clips along with the exclusion criteria, including the occurrence of (un)diagnosed mood and anxiety disorders. A medical history questionnaire targeting such disorders was administered together with DASS-21 (Lovibond and Lovibond 1995): a standardised psychometric test measuring depression, anxiety, and stress levels. Taking such precautionary measures eventually precluded potentially vulnerable individuals from participating in the experiments.

2.5. Limitations and future research directions

The present PhD project has provided novel insights into research on mood and bilingual language processing. However, the discussion of the observed findings has revealed potential limitations, which in turn can inspire future research directions. First, Research article 1 (Naranowicz et al. 2022a) showed that the observed facilitatory effects of a positive relative to a negative mood on RTs were limited to females, with no between-mood difference in males, corroborating previous electrophysiological evidence (Federmeier et al. 2001). Interestingly, such a gender-dependent pattern in a negative mood is also likely to be modulated by the experienced physiological arousal, as an increase in arousal was accompanied by faster RTs in females (i.e. a negative correlation) and slower RTs in males (i.e. a positive correlation) in the negative mood condition. Such a female advantage is consistent with previous research pointing to increased sensitivity to emotions in females (e.g. Goldstein et al. 2001) as well as increased reactivity to strongly affective stimuli (e.g. Bianchin and Angrilli 2012; see also Joseph et al. 2020 for a review). Consequently, only females participated in Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022), limiting the generalisability of the observed findings to a female cohort of the bilingual population. As noticed in Research article 4 (Naranowicz 2022), there seems to exist a gender bias in research on mood–language interactions. Therefore, future research should adopt an inclusive approach and focus on cross-sex comparisons, additionally treating gender as a non-binary social construct. This seems to be particularly crucial, as the population of non-binary persons remains marginalised and under-investigated (Richards et al. 2016). Moreover, instead of categorising participants based on their sex, researchers could measure the gender roles adopted by their participants (i.e. the degree to which they identify themselves with stereotypically feminine, masculine, or androgynous traits). To this aim, one could, for instance, administer the Bem Sex-Role Inventory (Bem 1974) – a self-report questionnaire measuring different aspects of hypothesised psychological gender traits, which has been widely used in gender research. Since being sensitive and emotional is stereotypically perceived as a feminine trait, one could expect that both feminine females and feminine males experience stronger mood effects on language comprehension than masculine females and masculine males.

Second, the findings of the three experiments are also limited to proficient unbalanced bilingual speakers who acquired their L2 in a formal context. Such a methodological decision was dictated by previous bilingual research on emotional language processing, revealing that bilingual persons with such a linguistic profile are particularly desensitised to L2 emotional content (see Caldwell-Harris 2015 for a review), as well as the availability of such a group of bilinguals. Such a limitation might, however, be a fruitful area for further work, which could concentrate on mood effects on language in bilingual speakers with various linguistic backgrounds, including non-proficient or early bilinguals.

Finally, recent evidence has pointed to various internal and external factors that may potentially modulate mood effects on language processing, which should therefore be taken into account in future research. First, behavioural research has shown that a negative mood may inhibit predictive sentence processing to a greater extent in older than younger adults in a monolingual context (Liu 2021). As accumulating evidence has demonstrated that older bilinguals compared to older monolinguals exhibit better executive functions (see Rossi and Diaz 2016 for a review), it could be hypothesised that language comprehension might be impaired by a negative mood to a lesser extent in older bilingual than monolingual speakers. Second, recent electrophysiological research has suggested that the effectiveness of negative mood induction may increase in the individuals more susceptible to seasonal changes (Höller et al. 2022). For this reason, future research could benefit from longitudinal designs measuring mood effects on language comprehension in summer and winter. Given that many depressive symptoms aggravate in winter in both clinical and non-clinical populations (see Øverland et al. 2020 for a review), it can be hypothesised that a negative mood may overall exert stronger effects on cognition, including semantic processing, in winter than in summer. Third, anecdotal evidence suggests that menstrual cycles and the hormonal changes that accompany them affect the experienced mood. Though conflicting empirical evidence on the role of menstruation-dependent hormones in mood fluctuations has thus far been reported (see Gloe et al. 2022 for a review), some evidence has actually suggested that females may experience an increased negative mood during the premenstrual phase (see Romans et al. 2012 for a review). Future research could include female participants' menstrual phase as a likely co-variate to test if such a biological mechanism somewhat affects how mood modulates language comprehension and other cognitive processes. Such research direction is particularly important, as there seems to exist a rather negative stereotype linking female reproduction with some undesirable qualities and behaviours (e.g. being emotionally unstable and irritable).

Conclusion

The present PhD project examined whether and to what extent a positive and a negative mood modulate mechanisms engaged in language comprehension in the two languages of a bilingual from a behavioural and an electrophysiological perspective. Overall, one behavioural (Research article 1, Naranowicz et al. 2022a) and two electrophysiological (Research article 2, Naranowicz et al. 2022b; Research article 3, Jankowiak et al. 2022) experiments together with the literature review (Research article 4, Naranowicz 2022) reported here demonstrated that a positive and a negative mood differently modulate behavioural and electrophysiological indices of language comprehension in bilinguals' respective languages.

First, the electrophysiological findings from Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022) revealed that a positive and a negative mood differently affect cognitive mechanisms engaged in L1 and L2 comprehension, with different mood effects being observed for cognitive mechanisms underlying semantic expectancy and semantic plausibility. Manipulating semantic expectancy, Research article 2 (Naranowicz et al. 2022b) showed a facilitative effect of a positive relative to a negative mood on lexico-semantic processing in L1 but not L2, suggesting that lexico-semantic access to L2 may be "immune" to mood fluctuations, possibly due to increased implicit emotion regulation in L2 than L1 (Morawetz et al. 2017). Then, there was also an inhibitory effect of a negative mood on semantic integration and re-analysis in L2 than L1, pointing to the activation of a suppression mechanisms "protecting" bilinguals from the adverse effects of a negative mood (e.g. Wu and Thierry 2012). Manipulating semantic plausibility (i.e. general knowledge violations), Research article 3 (Jankowiak et al. 2022) revealed frequently reported increased cognitive efforts invested in semantic integration and re-analysis of semantically anomalous relative to literal and metaphoric content, with a reduction of such mechanisms in a negative mood. Such results point to a positive mood activating heuristics-based and assimilative thinking and a negative mood detail-oriented and accommodative thinking (e.g. Vissers et al. 2013), irrespectively of the language of operation.

Second, the behavioural findings based on the speed and accuracy of evaluative judgements in Research article 1 (Naranowicz et al. 2022a) revealed a positivity-driven temporal advantage in word recognition that may minimise frequently reported between-language differences (i.e. the fastest RTs to positive items in a positive mood in both L1 and L2). Such a mood-congruence effect may be associated with the activation of a positivity-driven assimilative mechanism in semantic memory, triggered by both a positive mood (e.g. Schwarz and Clore 1983) and positively laden content (e.g. Ito and Cacioppo 2005). Then, Research article 1 (Naranowicz et al. 2022a) also indicated that a facilitatory effect of a positive relative to a negative mood on word recognition speed may be limited to females, suggesting that they might be more susceptible to mood fluctuations than males (e.g. Bianchin and Angrilli 2012).

Third, another key behavioural finding based on the accuracy of meaningfulness judgements in Research article 2 (Naranowicz et al. 2022b) and Research article 3 (Jankowiak et al. 2022) revealed that a facilitatory effect of a positive relative to a negative mood on sentence comprehension may occur when task demands are optimally challenging, with the strongest facilitatory effect being observed for literal meanings. This suggests that a positive mood may sensitise us to the most relevant contextual information (e.g. Wang et al. 2016). Moreover, Research article 3 (Jankowiak et al. 2022) also demonstrated that a positive relative to a negative mood may improve the recognition of figurative language (i.e. novel metaphors) in L1 but not L2. This may indicate that meaning creation processes are too cognitively taxing in L2 (e.g. Jankowiak et al. 2021) for a positive mood effect to occur.

Though the present PhD project did not focus on practical consequences of being in a given mood for language comprehension, it still carries some indirect implications. First, it can be tentatively concluded that a positive mood may enhance written language comprehension in L1 (e.g. reading a novel in L1), by sensitising the reader to the most important information in a given context. Note here that all experimental studies conducted for the present PhD project were based on written language comprehension, making it difficult to draw valid conclusions regarding communicative interactions based on spoken language. Then, the findings from Research article 3 (Jankowiak et al. 2022), on the one hand, suggest that reading and verifying factual texts in both L1 and L2 (e.g. expository essays, news reports, instructions, recipes, records of history, etc.) might be enhanced when the reader is in a bad mood. Such a negative affective state is expected to trigger detail-oriented thinking, which might help the reader verify the accuracy of a given piece of information. Research article 3 (Jankowiak et al. 2022), on the other hand, suggests that figurative language comprehension in L1 (e.g. reading poetry full of metaphors) may be facilitated when the reader is in a positive mood.

All in all, the findings of the present PhD project offer novel insights into research on affect and bilingualism, demonstrating that whether a bilingual person is in a positive or a negative mood determines how well they comprehend their respective languages. Nevertheless, further research is still needed to better understand potential modulatory factors of such mood–language interactions, including gender and individual differences in bilinguals' linguistic profiles.

Abstract

Life is not a neutral experience (Izard 2007). Mood unobtrusively yet pervasively influences our cognitive processes, including those engaged in language comprehension (Naranowicz 2022). Much research has demonstrated that a positive mood can be associated with heuristics-based and assimilative thinking whereas a negative mood with detail-oriented and accommodative thinking (Forgas 2017). Strikingly, while growing research attention has been devoted to cognitive mechanisms engaged in the comprehension of the native language (L1), little is known about if and how a positive and a negative mood affect the comprehension of the non-native language (L2; Kissler and Bromberek-Dyzman 2021). Given that accumulating evidence has pointed to bilingual speakers experiencing decreased sensitivity to emotional content in L2 (Jończyk 2016) as well as increased activation of implicit emotion regulation mechanisms in L2 than L1 (Morawetz et al. 2017), it can be hypothesised that a positive and a negative mood differently interact with L1 and L2 comprehension.

To address this research gap, the present PhD project aimed to investigate whether and how a positive and a negative mood affect behavioural and electrophysiological responses to L1 and L2, paying particular attention to cognitive mechanisms engaged in language comprehension. To address this research question, one behavioural (Research article 1, Naranowicz et al. 2022a) and two electrophysiological (Research article 2, Naranowicz et al. 2022b; Research article 3, Jankowiak et al. 2022) experiments were conducted, supplemented by a critical literature review (Research article 4, Naranowicz 2022).

Research article 1 (Naranowicz et al. 2022a) concentrated on mood effects on emotional word processing in L1 and L2. There was a facilitatory effect of a positive relative to a negative mood on the speed of evaluative judgements in females only, suggesting that females may be more sensitive to mood fluctuations than males (Bianchin and Angrilli 2012). Also, positive words were responded to equally fast in L1 and L2 in a positive but not a negative mood, suggesting that positive content might be encoded in a more assimilative manner than negative content, boosting its meaning retrieval from semantic memory in a positive mood (Faul and LaBar 2022).

Research article 2 (Naranowicz et al. 2022b) explored mood effects on meaningful and meaningless sentence comprehension in L1 and L2. There was a facilitatory effect of a positive mood on lexico-semantic access to L1 relative to L2, suggesting that bilinguals may be "immune" to mood changes in L2 due to increased activation of emotion regulation mechanisms (Morawetz et al. 2017). Moreover, semantic integration and re-analysis were suppressed in a negative mood in L2 relative to L1, pointing to the activation of a protective suppression mechanism (Wu and Thierry 2012).

Research article 3 (Jankowiak et al. 2022) investigated mood effects on meaningful (literal), meaningless (anomalous), and novel metaphoric sentences in L1 and L2. While the lexico-semantic stage was unaffected by mood changes, the semantic integration and re-analysis of meaningless sentences were more cognitively taxing than of meaningful and novel metaphoric sentences, with no such difference in a negative mood. Such a pattern points to the activation of heuristics-based and assimilative processing in a positive mood, which was suppressed in a negative mood (Vissers et al. 2013).

Research article 4 (Naranowicz 2022) revisited previous research on mood and semantic processes, paying closer attention to theoretical accounts, methodological considerations, and previous behavioural and electrophysiological evidence.

All in all, the findings of the present PhD project offer novel insights into research on affect and bilingualism, suggesting that, in addition to language proficiency levels, mood determines how well bilinguals comprehend semantic meanings in their respective languages.

Streszczenie

Życie nie jest doświadczeniem neutralnym (Izard 2007). Nastrój dyskretnie, ale znacząco wpływa na nasze procesy poznawcze, w tym na rozumienie języka (Naranowicz 2022). Wiele badań naukowych wykazało, że pozytywny nastrój można powiązać z myśleniem asymilacyjnym i opartym na heurystyce, a nastrój negatywny z myśleniem akomodacyjnym i zorientowanym na szczegóły (Forgas 2017). Co ciekawe, podczas gdy coraz większą uwagę w badaniach poświęca się mechanizmom poznawczym zaangażowanym w rozumienie języka ojczystego (L1), niewiele wiadomo o tym, czy i jak pozytywny i negatywny nastrój wpływają na rozumienie języka obcego (L2; Kissler i Bromberek-Dyzman 2021). Jako, że coraz więcej dowodów wskazuje, że osoby dwujęzyczne doświadczają zmniejszonej wrażliwości na treści emocjonalne w L2 (Jończyk 2016), a także zwiększonej aktywacji ukrytych mechanizmów regulacji emocji w L2 niż L1 (Morawetz et al. 2017), można postawić hipotezę, iż pozytywny i negatywny nastrój inaczej oddziaływają na rozumienie L1 i L2.

Aby wypełnić tę lukę badawczą, niniejszy projekt doktorski miał na celu zbadanie czy i jak pozytywny i negatywny nastrój wpływają na behawioralne i elektrofizjologiczne reakcje w L1 i L2, zwracając szczególną uwagę na mechanizmy poznawcze zaangażowane w rozumienie języka. Aby odpowiedzieć na to pytanie badawcze, przeprowadzono jeden eksperyment behawioralny (Artykuł 1, Naranowicz et al. 2022a) i dwa eksperymenty elektrofizjologiczne (Artykuł 2, Naranowicz et al. 2022b; Artykuł 3, Jankowiak et al. 2022), uzupełnione przez krytyczny przegląd literatury (Artykuł 4, Naranowicz 2022).

Artykuł 1 (Naranowicz et al. 2022a) był poświęcony wpływowi nastroju na przetwarzanie słów emocjonalnych w L1 i L2. Zaobserwowano sprzyjający wpływ pozytywnego w stosunku do negatywnego nastroju na szybkość ocen emocjonalności słów tylko u kobiet, co sugeruje, że kobiety mogą być bardziej wrażliwe na wahania nastroju niż mężczyźni (Bianchin i Angrilli 2012). Osoby badane reagowały także równie szybko na pozytywne słowa w L1 i L2 w pozytywnym ale nie negatywnym nastroju, co sugeruje, że treści pozytywne mogą być kodowana w sposób bardziej asymilacyjny niż treści negatywne, co ułatwia wyszukiwanie ich znaczenia w pamięci semantycznej w pozytywnym nastroju (Faul i LaBar 2022).

Artykuł 2 (Naranowicz et al. 2022b) dotyczył wpływu nastroju na rozumienie sensownych i bezsensownych zdań w L1 i L2. Zaobserwowano korzystny wpływ pozytywnego nastroju na dostęp leksykalno-semantyczny w L1 w stosunku do L2, co sugeruje, że osoby dwujęzyczne mogą być „odporne" na zmiany nastroju w L2 ze względu na zwiększoną aktywację mechanizmów regulacji emocji (Morawetz et al. 2017). Ponadto integracja semantyczna i ponowna analiza semantyczna zostały przyćmione w negatywnym nastroju w L2 w stosunku do L1, co wskazuje na aktywację ochronnych mechanizmów tłumienia (Wu i Thierry 2012).

Artykuł 3 (Jankowiak et al. 2022) poświęcony był wpływowi nastroju na sensowne (dosłowne), bezsensowne (anomalne) i nowe metaforyczne zdania w L1 i L2. Podczas gdy zmiany nastroju nie miały wpływu na procesy leksykalno-semantyczne, integracja semantyczna i ponowna analiza semantyczna zdań bezsensownych były bardziej obciążające poznawczo niż zdań sensownych i nowych metafor. Nie zaobserwowano jednak takiej różnicy w nastroju negatywnym. Taki schemat wskazuje na aktywację przetwarzania heurystycznego i asymilacyjnego w nastroju pozytywnym, które zostało stłumione w nastroju negatywnym (Vissers i in. 2013).

W Artykule 4 (Naranowicz 2022) dokonano przeglądu wcześniejszych badań nad nastrojem i procesami semantycznymi, zwracając szczególną uwagę na rozważania teoretyczne i metodologiczne, a także wcześniejsze dowody behawioralne i elektrofizjologiczne.

Ogółem, wyniki tego projektu doktorskiego oferują nowy wgląd w badania nad afektem i dwujęzycznością, pokazując, że poza poziomami biegłości językowej, nastrój decyduje o jakości rozumienia znaczeń semantycznych w poszczególnych językach osób dwujęzycznych.

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Appendix A: Research article 1 (Naranowicz et al. 2022a): Author contribution statement (Polish)

Poznań, 23 listopada 2022

Oświadczenie o wkładzie autorów i autorek

Naranowicz, M., Jankowiak, K., & Bromberek-Dyzman, K. (2022). Mood and gender effects in emotional word processing in unbalanced bilinguals. *International Journal of Bilingualism*, 13670069221075646. https://doi.org/10.1177/13670069221075646

Autor oraz współautorki artykułu naukowego „Mood and gender effects in emotional word processing in unbalanced bilinguals", opublikowanego w International Journal of Bilingualism 28 marca 2022 r., niniejszym deklarują swój następujący wkład w powstanie artykułu:

- **Marcin Naranowicz** (70%): projekt badania (konceptualizacja), przygotowanie materiałów, zaprogramowanie eksperymentu, zbieranie danych, analiza danych, wizualizacja danych, napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzja i redagowanie);
- **Katarzyna Jankowiak** (15%): napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzja i redagowanie);
- **Katarzyna Bromberek-Dyzman** (15%): projekt badania (konceptualizacja); napisanie manuskryptu (recenzja i redagowanie).

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Appendix B: Research article 1 (Naranowicz et al. 2022a): Author contribution statement (English)

Poznań, 23rd November 2022

Author contribution statement

Naranowicz, M., Jankowiak, K., & Bromberek-Dyzman, K. (2022). Mood and gender effects in emotional word processing in unbalanced bilinguals. *International Journal of Bilingualism*, 13670069221075646. https://doi.org/10.1177/13670069221075646

All co-authors of the research article titled "Mood and gender effects in emotional word processing in unbalanced bilinguals," published in International Journal of Bilingualism on 28th March 2022, hereby declare that they have contributed to the research article in the following way:

- **Marcin Naranowicz** (70%): study design (conceptualisation), material preparation, experiment programming, data collection, data analyses, data visualisation, manuscript writing (original draft preparation, reviewing, and editing);
- **Katarzyna Jankowiak** (15%): manuscript writing (original draft preparation, reviewing, and editing);
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Appendix C: Research article 2 (Naranowicz et al. 2022b): Author contribution statement (Polish)

Poznań, 23 listopada 2022

Oświadczenie o wkładzie autorów i autorek

Naranowicz, M., Jankowiak, K., Kakuba, P., Bromberek-Dyzman, K., & Thierry, G. (2022). In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages. *Brain Sciences*, 12(3), 316. https://doi.org/10.3390/brainsci12030316

Wszyscy współautorzy oraz współautorki artykułu naukowego „In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages", opublikowanego w Brain Sciences 26 lutego 2022 r., niniejszym deklarują swój następujący wkład w powstanie artykułu:

- **Marcin Naranowicz** (55%): konceptualizacja, metodologia, oprogramowanie, walidacja, analiza formalna, badanie (zbieranie danych), zasoby, przechowywanie danych, napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzja i redagowanie), wizualizacja danych, administracja projektu i pozyskanie funduszy;
- **Katarzyna Jankowiak** (20%): konceptualizacja, metodologia, walidacja, analiza formalna, badanie (zbieranie danych), przechowywanie danych i napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzja i redagowanie);
- **Patrycja Kakuba** (5%): badanie (zbieranie danych), przechowywanie danych i napisanie manuskryptu (recenzja i redagowanie);
- **Katarzyna Bromberek-Dyzman** (10%): konceptualizacja, metodologia, pisanie manuskryptu (recenzja i edycja), nadzór;
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Appendix D: Research article 2 (Naranowicz et al. 2022b): Author contribution statement (English)

Poznań, 23rd November 2022

Author contribution statement

Naranowicz, M., Jankowiak, K., Kakuba, P., Bromberek-Dyzman, K., & Thierry, G. (2022). In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages. *Brain Sciences*, 12(3), 316. https://doi.org/10.3390/brainsci12030316

All co-authors of the research article titled "In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages," published in Brain Sciences on 26th February 2022, hereby declare that they have contributed to the research article in the following way:

- **Marcin Naranowicz** (55%): conceptualisation, methodology, software, validation, formal analysis, investigation (data collection), resources, data curation, manuscript writing (original draft preparation, reviewing, and editing), data visualisation, project administration, and funding acquisition;
- **Katarzyna Jankowiak** (20%): conceptualisation, methodology, validation, formal analysis, investigation (data collection), data curation, and manuscript writing (original draft preparation, reviewing, and editing);
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- **Katarzyna Bromberek-Dyzman** (10%): conceptualisation, methodology, manuscript writing (reviewing and editing), and supervision;
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Appendix E: Research article 3 (Jankowiak et al. 2022): Author contribution statement (Polish)

Poznań, 23 listopada 2022

Oświadczenie o wkładzie autorów i autorek

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): 1–10. https://doi.org/10.1016/j.bandl.2022.105188

Autorka oraz współautorzy artykułu naukowego "Positive and negative moods differently affect creative meaning processing in both the native and non-native language", opublikowanego w Brain and Language 12 października 2022 r., niniejszym deklarują swój następujący wkład w powstanie artykułu:

- **Katarzyna Jankowiak** (45%): konceptualizacja, przechowywanie danych, analiza formalna, przeprowadzenie badania, metodologia, administracja projektu, zasoby, oprogramowanie, nadzór, walidacja, napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzowanie i redagowanie);
- **Marcin Naranowicz** (45%): konceptualizacja, przechowywanie danych, analiza formalna, pozyskanie funduszy, przeprowadzenie badania, metodologia, administracja projektu, zasoby, oprogramowanie, walidacja, wizualizacja, napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzowanie i redagowanie);
- **Guillaume Thierry** (10%): konceptualizacja, analiza formalna, napisanie manuskryptu (recenzowanie i redagowanie).

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Appendix F: Research article 3 (Jankowiak et al. 2022): Author contribution statement (English)

Poznań, 23rd November 2022

Author contribution statement

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): 1–10. https://doi.org/10.1016/j.bandl.2022.105188

All co-authors of the research article titled "Positive and negative moods differently affect creative meaning processing in both the native and non-native language," published in Brain and Language on 12th October 2022, hereby declare that they have contributed to the research article in the following way:

- **Katarzyna Jankowiak** (45%): conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, manuscript writing (original draft preparation, reviewing, and editing);
- **Marcin Naranowicz** (45%): conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, validation, visualization, manuscript writing (original draft preparation, reviewing, and editing);
- **Guillaume Thierry** (10%): conceptualization, formal analysis, manuscript writing (reviewing, and editing).

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Appendix G: Research article 4 (Naranowicz 2022): Author contribution statement (Polish)

Poznań, 23 listopada 2022

Oświadczenie o wkładzie autorów i autorek

Naranowicz, Marcin. 2022. "Mood effects on semantic processes: Behavioural and electrophysiological evidence". *Frontiers in Psychology* 13: 1014706. https://doi.org/10.3389/fpsyg.2022.1014706.

Autor artykułu naukowego "Mood effects on semantic processes: Behavioural and electrophysiological evidence", opublikowanego w Frontiers in Psychology 11 listopada 2022 r., niniejszym deklaruje swój następujący wkład w powstanie artykułu:

- **Marcin Naranowicz** (100%): konceptualizacja, napisanie manuskryptu (przygotowanie oryginalnego tekstu, recenzja i redakcja).

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Appendix H: Research article 4 (Naranowicz 2022): Author contribution statement (English)

Poznań, 23rd November 2022

Author contribution statement

Naranowicz, Marcin. 2022. "Mood effects on semantic processes: Behavioural and electrophysiological evidence". *Frontiers in Psychology* 13: 1014706. https://doi.org/10.3389/fpsyg.2022.1014706.

The author of the research article titled "Mood effects on semantic processes: Behavioural and electrophysiological evidence," published in Frontiers in Psychology on 11th November 2022, hereby declare that he has contributed to the research article in the following way:

- **Marcin Naranowicz** (100%): conceptualisation, manuscript writing (original draft preparation, reviewing, and editing).

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Appendix I: Research article 1 (Naranowicz et al. 2022a): Ethics approval

UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU
Komisja Etyczna ds. badań prowadzonych z udziałem ludzi

Uchwała nr 28/2018/2019
Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu
ds. badań naukowych prowadzonych z udziałem ludzi
z dnia 3 czerwca 2019 roku

w sprawie projektu badawczego: ***Wpływ nastroju na przetwarzanie słów emocjonalnych w dwujęzyczności: Badanie behawioralne.***
Na podstawie § 4 ust. 4 Regulaminu Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi (zarządzenie Rektora Uniwersytetu im. Adama Mickiewicza w Poznaniu nr 180/2013/2014) Komisja Etyczna Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi, zwana dalej Komisją, uchwala co następuje:

1. Na podstawie złożonego przez **Pana mgra Marcina Naranowicza** wniosku, Komisja opiniuje **pozytywnie** projekt badawczy: ***Wpływ nastroju na przetwarzanie słów emocjonalnych w dwujęzyczności: Badanie behawioralne.***
2. Uchwała została podjęta jednogłośnie i wchodzi w życie z dniem podjęcia.

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Appendix J: Research article 2 (Naranowicz et al. 2022b): Ethics approval

UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU
Komisja Etyczna ds. badań prowadzonych z udziałem ludzi

Uchwała nr 34/2019/2020
Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu
ds. badań naukowych prowadzonych z udziałem ludzi
z dnia 3 lutego 2020 roku

w sprawie projektu badawczego: ***Wpływ nastroju na procesy semantyczne w dwujęzyczności – badanie EEG.***

Na podstawie § 4 ust. 4 Regulaminu Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi (zarządzenie Rektora Uniwersytetu im. Adama Mickiewicza w Poznaniu nr 180/2013/2014) Komisja Etyczna Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi, zwana dalej Komisją, uchwala co następuje:

1. Na podstawie złożonego przez **pana mgra Marcina Naranowicza** wniosku, Komisja opiniuje **pozytywnie** projekt badawczy: ***Wpływ nastroju na procesy semantyczne w dwujęzyczności – badanie EEG***.
2. Uchwała została podjęta jednogłośnie i wchodzi w życie z dniem podjęcia.

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Appendix K: Research article 3 (Jankowiak et al. 2022): Ethics approval

UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU
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Uchwała nr 1/2020/2021
Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu
ds. badań naukowych prowadzonych z udziałem ludzi
z dnia 8 lutego 2021 roku

w sprawie projektu badawczego: "Rola nastroju w przetwarzaniu języka metaforycznego w dwujęzyczności: Badanie z wykorzystaniem potencjałów wywołanych"

Na podstawie § 4 ust. 4 Regulaminu Komisji Etycznej Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi (zarządzenie Rektora Uniwersytetu im. Adama Mickiewicza w Poznaniu nr 180/2013/2014) Komisja Etyczna Uniwersytetu im. Adama Mickiewicza w Poznaniu ds. badań naukowych prowadzonych z udziałem ludzi, zwana dalej Komisją, uchwala co następuje:

1. Na podstawie złożonego przez **Panią dr Katarzynę Jankowiak** wniosku, Komisja opiniuje **pozytywnie** projekt badawczy: "Rola nastroju w przetwarzaniu języka metaforycznego w dwujęzyczności: Badanie z wykorzystaniem potencjałów wywołanych".
2. Uchwała została podjęta jednogłośnie i wchodzi w życie z dniem podjęcia.

Przewodnicząca
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Appendix L: Research article 1 (Naranowicz et al. 2022a)

Naranowicz, Marcin, Katarzyna Jankowiak and Katarzyna Bromberek-Dyzman. 2022. "Mood and gender effects in emotional word processing in unbalanced bilinguals", *International Journal of Bilingualism* 13670069221075646. doi: https://doi.org/10.1177/13670069221075646.

Original Article

The International Journal *of* Bilingualism

International Journal of Bilingualism
1–22

DOI: 10.1177/13670069221075646
journals.sagepub.com/home/ijb
SAGE

Mood and gender effects in emotional word processing in unbalanced bilinguals

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Abstract

Aims and objectives: We aimed to explore the relationship between mood and emotional word processing in the bilingual context, as modulated by participants' gender.
Methodology: We presented mood-inducing film clips to 28 female and 28 male unbalanced Polish–English bilinguals to put them in positive and negative moods. Participants were asked to decide if native language (L1) and non-native language (L2) single words were positive, negative, or neutral (an emotive decision task).
Data and analysis: We analysed participants' subjective mood ratings pre- and post-experimentally together with speed (a linear mixed-effects model) and accuracy (a generalised mixed-effects model) of their responses to single L1 and L2 words.
Findings: The results revealed an interaction between mood and language as dependent on word valence, whereby faster reaction times (RTs) were observed to L1 than L2 neutral words only in a positive mood and to L2 positive words in a positive than negative mood. We also observed a response facilitation in a positive compared to negative mood, yet only in females. Finally, we observed faster and more accurate responses to positive and negative compared to neutral words, irrespective of gender and language of operation. Altogether, the results suggest that mood influences how unbalanced bilinguals respond to emotional words and shed a novel light on the role of participants' gender in emotional word processing.
Originality: This study extends monolingual research on emotional word processing to the bilingual context and shows how word valence modulates the way unbalanced bilinguals, being put in positive and negative moods, respond to L1 and L2 words. Our results also offer novel insights into research on mood and language, demonstrating that females can be more susceptible to mood changes than males.
Significance: Our results highlight the importance of controlling participants' mood and gender in research on emotional language processing in both monolingual and bilingual contexts.

Keywords

Mood, emotional word processing, bilingualism, gender differences, behavioural measures

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Introduction

Growing evidence has pointed to differences in unbalanced bilinguals exposed to an affective content in their native language (L1) and non-native language (L2), with L2 typically being experienced as less emotionally resonant than L1 (see Jończyk, 2016, for a review). Also, unbalanced bilinguals have been observed to unconsciously activate emotion-regulation mechanisms when using their L2 (Morawetz et al., 2017). Crucially, building upon previous monolingual research (e.g., Chwilla et al., 2011; van Berkum et al., 2013), recent evidence has suggested that one of the factors affecting emotional word processing in the bilingual context might be mood – current affective background state one experiences (Kissler & Bromberek-Dyzman, 2021). Yet, little attention has been devoted to investigating underlying mechanisms governing the relationship between mood and bilingualism in the context of emotional word processing. Interestingly, consistent with previous studies pointing to increased emotional sensitivity and expressiveness in females compared to males (see McCormick et al., 2016, for a review), monolingual research has also suggested that females can be more susceptible to mood effects on language processing than males (Federmeier et al., 2001). Yet, the relationship between mood and gender in the bilingual context has so far been under-investigated. Therefore, the present behavioural study aimed to explore the relationship between mood and emotional word processing in the bilingual context, taking into account possible gender differences. To this end, having watched positive and negative mood-inducing film fragments, unbalanced Polish–English bilingual females and males categorised L1 and L2 words as positive, negative, or neutral (i.e., an emotive decision task).

Affect and bilingualism

A growing body of survey (e.g., Dewaele, 2010), physiological (e.g., Jankowiak & Korpal, 2018), electrophysiological (e.g., Jończyk et al., 2016), and hemodynamic (e.g., Hsu et al., 2015) research has pointed to emotional detachment in unbalanced bilinguals operating in their L2. Such dampened emotional sensitivity in L2 relative to L1 has also been found in relation to decontextualised emotional words (e.g., Degner et al., 2012; Fan et al., 2017; Wu & Thierry, 2012; but see Eilola et al., 2007; Grabovac & Pléh, 2014; Ponari et al., 2015). For instance, in an event-related potential (ERP) study employing an implicit translation-priming paradigm, Wu and Thierry (2012) observed that while reading L2 negative words did not automatically activate L1 translation equivalents in unbalanced Chinese–English bilinguals, reading positive and neutral words resulted in language-coactivation. Researchers have linked such reduced L2 emotionality to different interconnected factors, including late age of L2 acquisition combined with low L2 proficiency (Harris et al., 2006), learning L2 mainly in the instructional (i.e., classroom) and not immersive environment (Degner et al., 2012; Dewaele, 2010), and weaker connection between lexico-semantic representations and affect in L2 due to infrequent use of emotional words (Degner et al., 2012; Opitz & Degner, 2012).

Interestingly, recent studies have also demonstrated that operating in L2 alone may result in the activation of emotion-regulation mechanisms, even when a task at hand is not language-related (e.g., Dylman & Bjärtå, 2019; Morawetz et al., 2017; Thoma, 2021). Morawetz et al. (2017), for instance, found that German–English bilinguals more effectively down-regulated the magnitude of their emotional response to affective pictures through content labelling (i.e., choosing a noun semantically related to a presented picture) in their L2 than L1. Altogether, the available research indicates not only that unbalanced bilinguals process emotional content in L2 less intensively than in L1, but also that they may automatically down-regulate their emotional responses through the active use of L2. It is still unknown, however, if such an emotion-regulation mechanism previously observed during L2 production could also occur during L2 comprehension.

Affect and gender

Previous monolingual research has repeatedly pointed to gender as another factor modulating emotional responding, with women considered as generally more emotional than men, irrespectively of their social status (Fischer, 1993). In line with this assumption, previous neuroimaging studies have found differences between males and females in brain regions responsible for emotional responses (Goldstein et al., 2001), as a result of which they exhibit a stronger physiological reactivity to affective stimuli (e.g., Bianchin & Angrilli, 2012; Codispoti et al., 2008). Compared to men, women have been additionally observed to report a more intense emotional response to external stimuli, irrespectively of their valence (Tobin et al., 2000; Vrana & Rollock, 2002), which was also confirmed by psychophysiological studies showing higher arousal and greater heart rate deceleration to emotional movies in females (e.g., Bianchin & Angrilli, 2012; Codispoti et al., 2008). Altogether, such findings are strongly indicative of an increased attention directed towards affective stimuli in women compared to men.

Interestingly, due to the fact that negative emotions are more strongly perceived by females than males (Fernández et al., 2012), women are assumed to be more prone to mood disorders (e.g., Fischer et al., 2004; Hillman et al., 2004). Although any potential gender differences in the influence of mood on emotional word processing has thus far been little researched, previous studies in cognitive psychology have suggested that females are more affected by mood than males (Luomala & Laaksonen, 2000; Martin, 2003) and are less likely to use cognitive control strategies to counter negative affect (Koch et al., 2007; Thayer et al., 1994).

Surprisingly little attention has, however, been devoted to studying gender differences in emotional language processing (e.g., Abbassi et al., 2019; Bauer & Altarriba, 2008; Schirmer et al., 2002). For instance, in a recent divided visual field priming study by Abbassi et al. (2019), females were observed to process emotional words faster than males, suggesting increased sensitivity of females towards the emotional content of words and, consequently, greater automaticity of emotional compared to neural word processing (e.g., Rodway et al., 2003; Van Strien & Van Beek, 2000). Taken together, while there exists growing evidence pointing to females being more susceptible to the influence of emotional stimuli and mood states, the relationship between gender and emotional word processing has thus far attracted scant scholarly attention.

Mood and emotional words

Mood has been referred to as an unobtrusive, slowly changing, and low-intensity emotional background state, fluctuating across time and ranging from feeling good (a positive mood) to feeling bad (a negative mood; Forgas, 2017; Herz et al., 2020). Mood has also been reported to affect language comprehension (van Berkum, 2018), including emotional word processing. Earlier behavioural studies (e.g., Ferraro et al., 2003; Olafson & Ferraro, 2001) observed that music-induced positive and negative moods facilitate participants' lexical decision latencies to mood-congruent words. Consistent with the associative network theory (Bower, 1981), the early studies suggested that moods may be represented as distinctive nodes in semantic memory, being linked to the nodes representing mood-congruent words. Yet, later research has revealed a less consistent pattern of results (e.g., Grzybowski et al., 2021; Pratt & Kelly, 2008; Sereno et al., 2015), rarely reporting mood-congruence effects hypothesised by Bower (1981). For instance, in a lexical decision task (LDT) study, Sereno et al. (2015) found that both positive and negative moods facilitated response accuracy and latencies to positive and negative words of low and high frequency compared to the baseline conditions – neutral words and no mood induction. They consequently suggested that mood may exert differential attentional effects on single word processing, with a positive mood broadening and a negative mood narrowing one's scope of attention.

More recently, in an ERP study, Kissler and Bromberek-Dyzman (2021) have observed that mood interacts with emotional word processing in the bilingual context. Unbalanced German–English bilinguals watched positively and negatively valenced film fragments and were asked to categorise L1 and L2 adjectives as positive, negative, or neutral (an evaluative decision task). Consistent with the research showing dampened emotional sensitivity to negatively valenced content in L2 (e.g., Jończyk et al., 2016; Wu & Thierry, 2012), behavioural results revealed a trend towards longer reaction times (RTs) to negative words in L2 than L1, with no between-language differences in RTs to positive and neutral words. Unlike for the behavioural data, Kissler and Bromberek-Dyzman (2021) observed an interactive mood and language effect within the N1 time window (125–200 ms), where L2 remained unaffected by mood changes, while the N1 (i.e., a neural marker of early lexical access) was left-lateralized over temporal sites in the positive mood condition in L1, with no lateralisation in the negative mood condition, regardless of word valence. The ERP results thus show that language-specific mood effects can be treated as a relevant social communicative context at least for early lexical access to emotional words, indicating that mood might differently modify word processing in L1 and L2. Yet, the role of gender in the interplay between mood and emotional word processing in the context of bilingualism remains under-investigated.

Research aims and hypotheses

The main aim of this study was to explore the relationship between mood (positive vs. negative) and emotional word processing (positive vs. negative vs. neutral) in the bilingual context (L1 vs. L2), focusing additionally on how participants' gender (female vs. male) modulates the process. Specifically, this study explored potential differences between males and females experiencing positive and negative moods in how fast and accurately they respond to L1 (Polish) and L2 (English) positive, negative, and neutral words. To this end, we experimentally induced positive and negative moods with short animated film clips in proficient Polish–English bilingual women and men and asked them to perform an evaluative decision task (i.e., decide if L1 and L2 words were positive, negative, or neutral) while their behavioural responses (i.e., RTs and accuracy rates) were being recorded.

Building upon the previous research, we put forward three main hypotheses. First, we predicted facilitation (i.e., as indexed by faster RTs) of word processing in the positive compared to negative mood condition (e.g., Chwilla et al., 2011; Hinojosa et al., 2017; van Berkum et al., 2013), the effect being stronger in females than males (e.g., Federmeier et al., 2001; Luomala & Laaksonen, 2000; Martin, 2003). Second, we hypothesised that the processing advantage (as indexed by faster RTs) in the positive compared to negative mood condition would be attenuated in L2 compared to L1 (e.g., Jończyk et al., 2016; Morawetz et al., 2017; Wu & Thierry, 2012). We also exploratorily analysed here if gender may further modulate the relationship between mood and language nativeness. Third, we predicted response facilitation (i.e., as indexed by faster RTs) of positive and negative compared to neutral words (e.g., Chen et al., 2015; Opitz & Degner, 2012; Ponari et al., 2015), the effect being more pronounced in females compared to males (e.g., Abbassi et al., 2019; Rodway et al., 2003; Van Strien & Van Beek, 2000).

Table 1. Participants' sociolinguistic and biographical data (means with 95% CI).

					L1	L2
Age	*Female*	20.9 [20.2, 21.5]				
	Male	21.5 [20.6, 22.4]				
Handedness[a]	*Female*	86.1 [79.4, 92.8]	*Proficiency*[b]	*Female*	n/a	77.6 [73.7, 81.5]
	Male	86.6 [79.8, 93.4]		*Male*		81.6 [76.9, 86.3]
Empathy[c]	*Female*	44.6 [41.2, 48.0]	*Proficiency*[d]	*Female*	94.8 [90.9, 98.6]	80.8 [75.8, 85.8]
	Male	41.6 [36.7, 46.6]		*Male*	90.9 [85.0, 96.7]	80.4 [70.5, 90.2]
Depression[e]	*Female*	10.2 [6.7, 13.7]	*Dominance*[d]	*Female*	58.4 [55.2, 61.6]	47.9 [44.7, 51.0]
	Male	9.8 [6.5, 13.1]		*Male*	57.9 [52.8, 63.0]	50.1 [42.5, 57.7]
Anxiety[e]	*Female*	8.8 [5.9, 11.7]	*Immersion*[d]	*Female*	79.3 [72.2, 86.4]	62.9 [57.4, 68.5]
	Male	5.4 [2.7, 8.1]		*Male*	80.9 [72.6, 89.3]	60.0 [52.1, 67.8]
Stress[e]	*Female*	14.4 [10.7, 18.0]	*Age of*	*Female*	n/a	8.5 [7.3, 9.8]
	Male	11.3 [8.2, 14.3]	*Acquisition*[d]	*Male*		8.9 [6.6, 11.2]

Note. Only the data for the final sample are included here. CI: confidence interval.
[a]Handedness Questionnaire (Oldfield, 1971).
[b]LexTALE (Lemhöfer & Broersma, 2012).
[c]Empathy Quotient (Baron-Cohen & Wheelwright, 2004, translated into Polish by Wainaina-Wozna).
[d]Language History Questionnaire 3.0 (LHQ; Li et al., 2020, translated into Polish by Naranowicz & Witczak).
[e]DASS-21 (Lovibond & Lovibond, 1995, translated into Polish by Makara-Studzińska et al.).

Methods

Participants

The original sample included 67 participants, 10 of whom (all females) were excluded from the analyses due to no reported changes in mood (see the *Results* section) and 1 of them, due to a technical mistake. Consequently, we analysed the data from 56 Polish–English bilinguals (28 females, 28 males) aged 20–26, who were (under-)graduate students of English Studies at the Faculty of English, Adam Mickiewicz University, Poznań, Poland. They acquired their L2 after the age of eight ($M_{AgeOfAcquisition}=8.70$, 95% confidence interval [CI] = [7.79, 9.60]) in the formal school setting in Poland and had not lived in the L2 (English) environment. Based on this information and Language History Questionnaire's (LHQ) dominance scores (Table 1; see Li et al., 2020: 2–4 for details regarding the calculation of the proficiency, dominance, and immersion scores), they were classified as late unbalanced Polish–English bilinguals (see De Groot, 2011). All participants were proficient learners of English (L2), as confirmed by the results of LexTALE (Lemhöfer & Broersma, 2012) and LHQ (Li et al., 2020). All participants were right-handed, did not report any language or mental disorders, and had normal or corrected-to-normal vision and hearing (for more details on participants' characteristics, see Table 1). Also, all participants were in a good general affective state, reporting low degrees of depression, anxiety, or stress around the time of data collection (see Table 1). Participants received extra credit points for participation.

Materials

Mood-inducing stimuli. Highly arousing, 90-second long, animated, affectively evocative film fragments were used to induce the target positive ($n=14$) or negative mood ($n=14$) (see *Supplementary material A*). The fragments had no spoken/written words to avoid priming participants with a language. A norming study was first conducted to ensure the affective evocativeness of the selected excerpts, involving 50 highly proficient Polish–English bilinguals (45 females, 5 males), aged 19–24 (Table 2). To this end, 58 film excerpts were rated on two 7-point Likert-type scales: (1)

Table 2. Norming studies: participants' characteristics (means with 95% CI).

	Mood-inducing stimuli	Linguistic stimuli
Age[a]	21.2 [20.7, 21.5]	22.7 [22.1, 23.5]
L1 Proficiency[b]	7.0 [7.0, 7.0]	7.0 [7.0, 7.0]
L2 Proficiency[b]	5.9 [5.7, 6.2]	5.6 [5.4, 5.7]
Years of L2 learning[a]	11.3 [10.7, 11.9]	15.3 [13.4 17.2]

CI: confidence interval.
[a]The score in years.
[b]Based on self-reported proficiency: 1 = *beginner*, 7 = *native speaker*.

valence (1 = *the film evokes strongly negative emotions*, 7 = *the film evokes strongly positive emotions*) and (2) arousal (1 = *the film makes me feel completely unaroused*, 7 = *the film makes me feel highly aroused*). They were divided into six pseudo-randomly ordered sets of 9–10 excerpts each. The two-sample Welch's *t*-tests revealed that the film clips selected to induce a positive mood were rated higher on valence than those selected to induce a negative mood ($M_{PositiveMood}$ = 5.34, 95% CI [5.17, 5.52]; $M_{NegativeMood}$ = 1.97, 95% CI [1.78, 2.16]), $t(20.98) = –24.94$, $p < .001$, while there was no difference between the two film types in arousal ratings ($M_{PositiveMood}$ = 3.62, 95% CI [3.06, 4.17]; $M_{NegativeMood}$ = 4.27, 95% CI [3.94, 4.59]), $t(20.98) = 1.90$, $p = .071$.

Linguistic stimuli. The linguistic stimuli included 240 single words: 120 English and 120 Polish abstract adjectives, including 40 negative (e.g., *lonely*), 40 neutral (e.g., *ongoing*), and 40 positive words (e.g., *awesome*) for each language (see *Supplementary material B*). The stimuli were controlled for and matched on a number of variables, which are described in detail in Table 2. The words used did not include translation equivalents. Polysemous words, Polish–English cognates and interlanguage homonyms and homographs were excluded from the experimental stimuli. In addition, to match the stimuli on word valence, arousal, and concreteness, a norming study was conducted, involving 60 highly proficient Polish–English bilinguals (51 females, 8 males, 1 non-binary), aged 19–31 (Table 2). None of these participants took part in the experiment proper.

Altogether, 180 Polish and 180 English adjectives were rated on three 7-point Likert-type scales for word valence, arousal, and concreteness. The words with the highest and the lowest scores on the word valence scale were classified as positive and negative, respectively, and 20 words above and below the mean – as neutral. Regarding the concreteness ratings, the words with the scores lower than 3.5 were classified as abstract and, then, included in the final set.

Two-way item-based repeated measures (RM) analysis of variances (ANOVAs) were conducted with Word valence (Positive, Negative, Neutral) and Language (Polish, English) as between-subject factors to test differences in participants' ratings and word properties (Table 3). For the word valence ratings, the analysis showed a main effect of Word valence, $F(2, 234) = 2{,}281.99$, $p < .001$, $\eta_p^2 = .95$, such that the neutral words were rated as less emotional than the positive and negative words, ps < .001. There was also a difference between the positive and negative words, $p < .001$. For the arousal ratings, the analysis also yielded a main effect of Word valence, $F(2, 234) = 282.30$, $p < .001$, $\eta_p^2 = .71$, whereby the neutral words were rated as less arousing than the positive and negative words, $p < .001$, but there was no difference in arousal between the positive and negative words, $p > .05$. The analysis showed no main effects and interactions for the concreteness ratings, ps > .05. Then, while the analysis of word length (i.e., the number of characters) revealed no main effects and interactions, the analysis of word frequency yielded a main effect of Language, $F(1, 234) = 125.22$, $p < .001$, $\eta_p^2 = .35$, whereby the L2 (English) words were more frequent than the L1 (Polish) words.

Table 3. Means (with 95% CI) of all controlled characteristics of the lexical stimuli.

		Frequency	Word valence	Arousal	Concreteness	Syllables	Letters
Polish (L1)	*Negative*	3.2 [3.2, 3.3]	2.2 [2.1, 2.3]	4.0 [3.7, 4.3]	2.6 [2.3, 2.9]	2.7 [2.5, 2.8]	7.3 [7.0, 7.5]
	Neutral	3.3 [3.2, 3.3]	4.2 [4.1, 4.3]	2.4 [2.2, 2.7]	3.5 [3.3, 3.8]	2.8 [2.6, 3.0]	7.2 [7.0, 7.4]
	Positive	3.3 [3.2, 3.4]	5.8 [5.6, 5.9]	4.0 [3.7, 4.4]	2.5 [2.3, 2.8]	2.7 [2.6, 2.9]	7.1 [7.0, 7.4]
English (L2)	*Negative*	3.8 [3.6, 4.0]	2.1 [1.9, 2.2]	4.3 [3.9, 4.7]	3.1 [2.8, 3.4]	2.2 [2.1, 2.3]	7.1 [7.0, 7.4]
	Neutral	3.8 [3.6, 3.9]	4.1 [4.0, 4.2]	2.4 [2.2, 2.7]	3.9 [3.6, 4.2]	2.5 [2.4, 2.7]	7.2 [7.0, 7.5]
	Positive	3.9 [3.8, 4.1]	5.9 [5.8, 6.0]	4.1 [3.8, 4.5]	2.9 [2.7, 3.2]	2.3 [2.1, 2.5]	7.4 [7.0, 7.6]

Measurements and ranges: (1) Frequency (based on SUBTLEX-UK; van Heuven et al., 2014; and SUBTLEX-PL; Mandera et al., 2015): (the Zipf scale) 1 = *the lowest frequency*, 7 = *the highest frequency*; (2) Word valence: 1 = *the word evokes strongly negative emotions*, 7 = *the word evokes strongly positive emotions*; (3) Arousal: 1 = *the word makes me feel completely unaroused*, 7 = *the word makes me feel highly aroused*; (4) Concreteness/abstractness: 1 = *the word is abstract*, 7 = *the word is concrete*; (5) Syllables: 2–4 syllables; (vi) Letters: 6–8 letters.
CI: confidence interval.

Altogether, these results indicate that emotional words were more arousing than neutral ones, the effect being language-non-specific, which is a frequently reported finding in emotion literature (e.g., Kousta et al., 2009; Opitz & Degner, 2012; Citron et al., 2014).

Procedure

The study was approved by the Human Research Ethics Committee of Adam Mickiewicz University, Poznań, Poland. The experiment was conducted at the Language and Communication Laboratory, Faculty of English, Adam Mickiewicz University, Poznań, Poland. There were two experimental sessions (with a 1-week interval), separately for the positive and negative mood induction (counterbalanced sequence). The same set of linguistic stimuli was used during both sessions. Participants were seated in a dimly lit and quiet booth, 70 cm away from a LED monitor with a screen resolution of 1280 × 1024 pixels.

A battery of questionnaires was first administered to build participants' linguistic and sociobiographical profiles and to control for potential mood induction adverse effects (see Table 1 for details). Then, participants evaluated their current mood prior to mood manipulation on a 7-point valence and arousal scales and the 20-item *Positive and Negative Affect Schedule* (PANAS; Watson et al., 1988, translated into Polish by Fajkowska & Marszał-Wiśniewska, 2009). E-prime 2.0 Software was used to present the stimuli and collect the RT and accuracy data. Participants performed an evaluative decision task – an affective categorisation task, wherein they decided if the presented words were positive/negative/neutral using keyboards (counterbalanced designation of keys).

First, participants watched three film excerpts to prime the target mood. Then, they responded to 20 words, followed by a single film excerpt presentation to keep them in the target mood. A fixation cross first appeared in the centre of the screen for 350 ms, followed by the presentation of a target word, which remained on-screen until response, yet no longer than for 2,000 ms, with an intertrial interval (ITI) of 500 ms. All words and film excerpts were presented randomly in cycles until the entire set of words in a given language block was rated. None of the words or film excerpts was repeated throughout one experimental session. Each session included one English (L2) and one Polish (L1) block (counterbalanced order). Finally, participants rated their current mood post-experimentally.

Study design and data analysis

All statistical analyses were performed in the R environment (Version 4.0; R Development Core Team, 2020). First, we analysed the effects of Time of testing (Pre-experiment, Post-experiment) and Film type (Positive, Negative) on participants' mood ratings. Mood was evaluated by means of the 7-point valence and arousal scales and the PANAS (Watson et al., 1988). For the valence and arousal scales, we used the same procedure as in the norming study (see the *Mood-inducing stimuli* subsection for details). Regarding the PANAS (Watson et al., 1988), participants self-reported their current emotions experienced on a 5-point Likert-type scale (1 = *very slightly or not at all*, 5 = *extremely*) with 10 positive (i.e., *active, alert, attentive, enthusiastic, excited, inspired, interested, proud, strong, determined*) and 10 negative (i.e., *afraid, scared, nervous, jittery, guilty, ashamed, irritable, hostile, upset, distressed*) adjectives. Then, the scores for the items signalling positive affect and negative affect were summed separately, and the final score was presented as the ratio of the sum of the positive affect scores and the sum of the negative affect scores. The obtained ratio values allowed us to observe if participants felt more positive (as indicated by positive ratio values) or more negative (as indicated by negative ratio values), and compare these values pre- relative to post-mood induction.

Then, we investigated whether Mood (Positive, Negative), Gender (Females, Males), Word valence (Positive, Negative, Neutral), and Language (Polish, English) had an impact on participants' response accuracy and log10-transformed RTs, with Mood, Word valence, and Language being within-subject variables and Gender, a between-subject variable. Responses below 200 ms (0.01% of response) and those deviating at least 2.5 standard deviations above and below the mean from all within-subjects (2.05% of outliers) or within-items (2.01% of outliers) factors were excluded from the analyses, resulting in a final rejection of 3.48% of the data. RT and accuracy data were analysed with a linear mixed-effects model (LMM) and a generalised linear mixed-effects model (GLMM), respectively (Baayen et al., 2008; Barr, 2013; Barr et al., 2013; Jaeger, 2008), using the *lme4* package for R (Version 1.1–23; Bates et al., 2015). A maximal model was first computed with a full random-effect structure, including subject- and item-related variance components for intercepts and by-subject 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., 2018). 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) are based on the Satterthwaite approximation for LMM (the *lmerTest* package, Version 3.1.2., Kuznetsova et al., 2017). Post hoc analyses were calculated using the *emmeans* package (Version 1.7.0; Lenth et al., 2022). All R scripts and raw data files used in the analyses are available here: https://osf.io/wf8s7/

Results

Mood induction

Following Rottenberg et al. (2018), 10 non-responders were identified (i.e., participants who reported no in-/decrease in the target mood subsequent to its manipulation) and excluded from the analyses (i.e., the mood manipulation had the intended effect in 85.29% of cases). A mood change was considered meaningful when (1) it exceeded at least one step on the 7-point valence scale in the expected direction pre- relative to post-mood induction in both mood conditions, and (2) the ratio values of summed ratings for positive and negative affect adjectives were positive in the

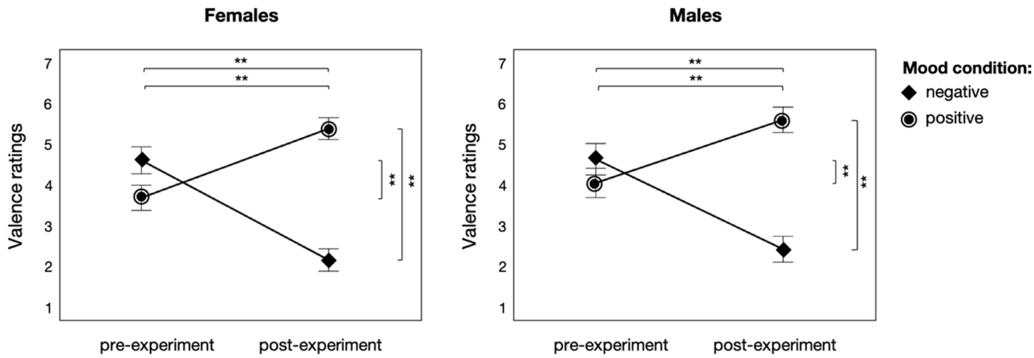

Figure 1. Mood ratings for the valence scale with 95% CI.

positive mood condition and negative in the negative mood condition and higher pre- relative to post-mood induction in both mood conditions.

The data from the final participant sample were subject to the mixed ANOVA, which yielded a two-way interaction between Time of testing and Film type for both the valence ratings, $F(1, 54)=480.17, p=.001, \eta_p^2=.90$ (see Figure 1), and the PANAS ratings, $F(1, 54)=293.33, p<.001, \eta_p^2=.84$. Planned paired-sample *t*-tests further showed that, in the positive mood condition, participants' post-experimental mood ratings ($M_{Valence}=5.46$, 95% CI [5.24, 5.69]; $M_{PANAS}=2.17$, 95% CI [2.01, 2.32]) were higher compared to the pre-experimental ones ($M_{Valence}=3.82$, 95% CI [3.59, 4.05]; $M_{PANAS}=1.51$, 95% CI [1.36, 1.67]). In contrast, in the negative mood condition, participants' post-experimental mood ratings ($M_{Valence}=2.29$, 95% CI [2.06, 2.51]; $M_{PANAS}=1.91$, 95% CI [1.76, 2.07]) were lower relative to the pre-experimental ones ($M_{Valence}=4.60$, 95% CI [4.37, 4.83]; $M_{PANAS}=0.22$, 95% CI [0.07, 0.38]). In addition to the interaction, the analysis yielded main effects of Film type, $F_{Valence}(1, 54)=25.78, p<.001, \eta_p^2=.65$; $F_{PANAS}(1, 54)=100.26, p<.001, \eta_p^2=.65$, and Time of testing, $F_{Valence}(1, 59)=32.66, p<.001, \eta_p^2=.32$; $F_{PANAS}(1, 54)=92.75, p=.001, \eta_p^2=.63$. Pairwise comparisons then revealed differences between participants' pre-experimental ($M_{Valence}=4.21$, 95% CI [4.03, 4.38]; $M_{PANAS}=1.71$, 95% CI [1.59, 1.83]) and post-experimental mood ratings ($M_{Valence}=3.88$, 95% CI [3.70, 4.05]; $M_{PANAS}=1.19$, 95% CI [1.07, 1.32]), $ps<.001$, and between the positive ($M_{Valence}=4.64$, 95% CI [4.44, 4.84]; $M_{PANAS}=1.84$, 95% CI [1.71, 1.97]) and negative mood conditions ($M_{Valence}=3.44$, 95% CI [3.24, 3.64]; $M_{PANAS}=1.07$, 95% CI [0.94, 1.20]), $ps<.001$ (see Figure 1). Also, the RM ANOVA showed no main effects and interactions for the arousal ratings, $ps>.05$. Therefore, the analyses confirmed that the mood induction procedure was successful both in the positive and negative mood conditions, irrespective of participants' gender, and showed that the intensity of participants' emotions was comparable across *all* conditions.

Response accuracy data

The analyses performed on accuracy rates revealed a fixed effect of Word valence, whereby neutral words ($M=80.34\%$, 95% CI [64.56, 96.13]) were responded to with lower accuracy compared to positive words ($M=91.01\%$, 95% CI [72.31, 100.00]), $b=1.34$, standard error (SE)$=0.26$, $z=5.08$, $p<.001$, and to negative words ($M=90.45\%$, 95% CI [71.95, 108.94]), $b=1.04$, $SE=0.26$, $z=4.05$, $p<.001$. Also, there was no difference in accuracy between positive and negative words, $b=0.30$, $SE=0.23$, $z=1.32$, $p=.187$.

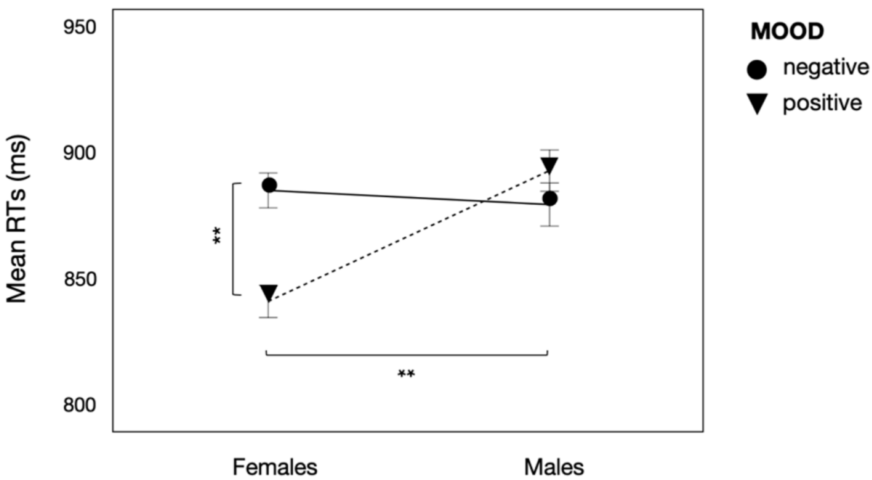

Figure 2. The mean response time data (ms) with 95% CI showing the relationship between mood and gender.

The analysis also revealed a significant three-way interaction between Language, Word valence, and Gender, $b = 0.74$, $SE = 0.25$, $z = 3.02$, $p = .003$. Post hoc comparisons revealed that while females responded to English positive words with greater accuracy than to English negative words ($M_{Positive} = 92.30\%$, 95% CI [65.13, 100.00]; $M_{Negative} = 89.50\%$, 95% CI [63.82, 100.00]), $b = 0.74$, $SE = 0.36$, $z = 2.09$, $p = .037$; there was no such difference for males ($M_{Positive} = 91.67\%$, 95% CI [64.86, 100.00]; $M_{Negative} = 91.93\%$, 95% CI [64.98, 100.00]), $b = 0.27$, $SE = 0.33$, $z = 0.84$, $p = .399$. All the remaining effects of response accuracy were also statistically non-significant, ps > .05.

RT data

The analyses performed on RTs revealed a fixed effect of Language, such that Polish words ($M = 888.60$ ms, 95% CI [883.96, 893.24]) were responded to faster than English words ($M = 923.50$ ms, 95% CI [918.75, 928.24]), $b = 0.017$, 95% CI [0.005, 0.028], $t(251.9) = 2.93$, $p = .004$. The analyses also revealed a fixed effect of Word valence, whereby positive words ($M = 837.52$ ms, 95% CI [832.45, 842.60]) were responded to faster than negative words ($M = 877.94$ ms, 95% CI [872.61, 883.27]), $b = 0.020$, 95% CI [0.005, 0.034], $t(234.6) = 2.71$, $p = .001$, as well as neutral words ($M = 1{,}009.99$ ms, 95% CI [1,003.85, 1,016.13]), $b = 0.084$, 95% CI [0.067, 0.101], $t(150.9) = 9.60$, $p < .001$. Then, negative words were responded to faster than neutral words, $b = 0.064$, 95% CI [0.048, 0.080], $t(181.6) = 7.76$, $p < .001$.

The analyses also showed a two-way interaction between Mood and Gender, $b = -4.18$, $SE = 1.75$, $t(5.46) = -2.39$, $p = .020$ (see Figure 2). Post hoc comparisons revealed that, in females, faster RTs were elicited in the positive compared to negative mood condition ($M_{PositiveMood} = 861.333$ ms 95% CI [855.38, 867.28]; $M_{NegativeMood} = 908.59$ ms, 95% CI [902.10, 915.09]), $b = -0.024$, 95% CI [–0.040, –0.007], $t(55.8) = -2.89$, $p = .006$, and there was no such between-mood difference in males ($M_{PositiveMood} = 937.16$ ms, 95% CI [930.24, 944.08]; $M_{NegativeMood} = 916.11$ ms, 95% CI [909.11, 923.11]), $b = -0.013$, 95% CI [–0.004, 0.030], $t(55.9) = 1.54$, $p = .130$. Also, females responded faster to stimuli in the positive mood condition than males, $b = -0.036$, 95% CI [–0.064, –0.007], $t(54.1) = -2.55$, $p = .014$, and there was no such between-group difference in the negative mood condition, $b = 0.001$, 95% CI [–0.030, 0.032], $t(55.4) = 0.06$, $p = .949$.

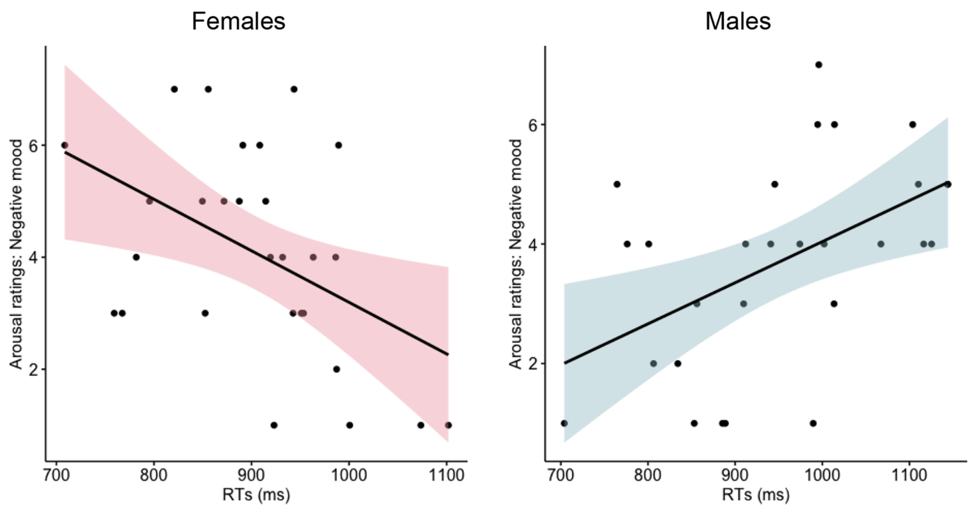

Figure 3. Correlation plots showing the relationship between arousal ratings in the negative mood condition and reaction times in females (left) and males (right).

Moreover, a correlational analysis pointed to a gender-dependent linear relationship between participants' RTs and their arousal ratings in the negative mood condition, with a positive correlation for males, $r = .50$, 95% CI [0.16, 0.74], $t(26) = 2.96$, $p = .007$, and a negative correlation for females, $r = -.46$, 95% CI [–0.71, –0.10], $t(26) = -2.62$, $p = .014$ (see Figure 3).

Finally, the analyses yielded a three-way interaction between Mood, Language, and Word valence, $b = -2.03$, $SE = 7.40$, $t(2.34) = -2.74$, $p = .007$, (see Figure 4). As regards neutral words, post hoc comparisons showed that Polish relative to English neutral words were responded to faster in the positive mood condition, $b = 2.03$, 95% CI [1.36, 3.92], $t(261.7) = 2.11$, $p = .036$, with no between-language difference in the negative mood condition, $b = 1.59$, 95% CI [–8.70, 3.04], $t(168.6) = 1.27$, $p = .204$ (see Table 4). As for positive words, post hoc comparisons revealed that English positive words in the negative mood condition were responded to slower than in the positive mood condition, $b = -1.42$, 95% CI [–2.80, –5.32], $t(77.1) = -2.07$, $p = .042$ as well as than Polish positive words in both the negative mood condition, $b = 1.89$, 95% CI [–8.52, 3.79], $t(260.6) = 1.96$, $p = .051$, as well as the positive mood condition, $b = 2.26$, 95% CI [1.50, 4.36], $t(248.6) = 2.11$, $p = .036$ (see Table 4). As for negative words, post hoc comparisons revealed that Polish compared to English negative words were responded to faster in the positive mood condition, $b = 2.13$, 95% CI [1.58, 4.10], $t(254.1) = 2.13$, $p = .034$, as well as the negative mood condition, $b = 2.12$, 95% CI [1.49, 4.10], $t(260.2) = 2.12$, $p = .035$ (see Table 4), resembling the main effect of Language reported above.

Furthermore, to address Hypothesis 3 predicting potential gender-specific effects of Word valence, we performed planned comparisons that revealed faster RTs to positive words ($M_{Female} = 813.38$ ms, 95% CI [734.47, 892.30]; $M_{Male} = 861.80$ ms, 95% CI [774.03, 949.56]) compared to neutral words ($M_{Female} = 989.99$ ms, 95% CI [899.33, 1,080.65]; $M_{Male} = 1{,}028.91$ ms, 95% CI [928.04, 1,129.79]) in both females, $b = 0.09$, 95% CI [0.07, 0.11], $t(105.4) = 8.00$, $p < .001$, and males, $b = 0.08$, 95% CI [0.06, 0.10], $t(99.9) = 7.39$, $p < .001$. Similarly, we also observed faster RTs for negative ($M_{Female} = 862.38$ ms 95% CI [786.14, 938.63]; $M_{Male} = 893.48$ ms, 95% CI [802.81, 984.16]) compared to neutral words in both females, $b = 0.06$, 95% CI [0.04, 0.08], $t(124.9) = 6.21$, $p < .001$, and males, $b = 0.07$, 95% CI [0.05, 0.09], $t(117.6) = 6.56$, $p < .001$. All the remaining effects of RTs were statistically non-significant, ps $> .05$.

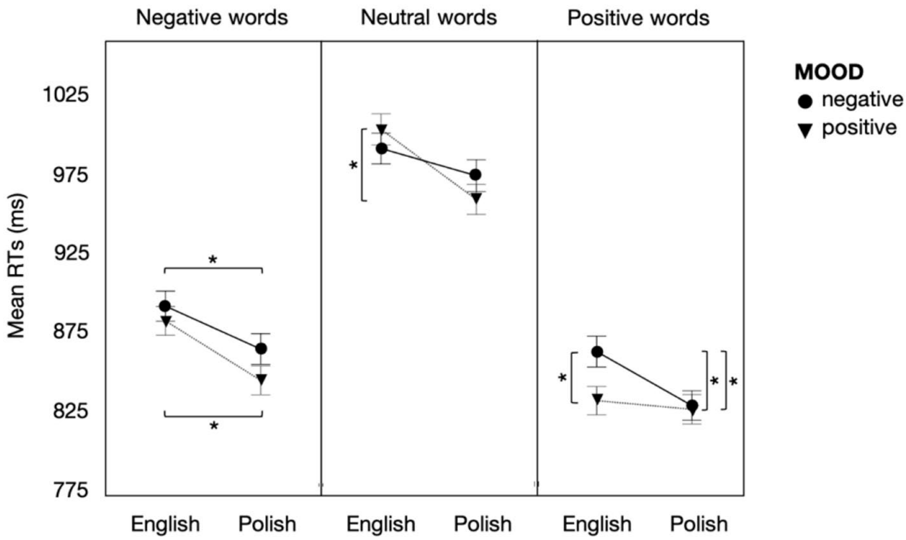

Figure 4. The mean response time data (ms) with 95% CI showing the relationship between mood, language, and valence.

Discussion

The aim of the present behavioural study was to extend monolingual research on mood and emotional word processing to the bilingual context, additionally accounting for possible gender differences. To this end, we put unbalanced Polish–English bilingual females and males into positive and negative moods using emotionally evocative film clips and asked them to perform an evaluative decision task on L1 and L2 positive, negative, and neutral words, recording their RTs and response accuracy.

Mood and language nativeness

The key research question addressed in this study was whether mood differently interacts with language in L1 and L2. We expected to observe response facilitation in a positive compared to negative mood being attenuated in L2 compared to L1 (e.g., Wu & Thierry, 2012; Jończyk et al., 2016; Morawetz et al., 2017). Instead, we observed an interaction between mood and language, which was dependent upon word valence. Specifically, we found (1) faster RTs to L1 compared to L2 neutral words in a positive mood, with no such a between-language difference for a negative mood; (2) faster RTs to L2 positive words in a positive compared to negative mood, with no such a between-mood difference in L1; and (3) faster RTs to L1 compared to L2 negative words, irrespective of the mood type.

First, shorter response latencies to L1 relative to L2 neutral words in a positive mood as well as to negative words in both mood conditions are consistent with the temporal delay assumption of the Bilingual Interactive Activation Plus model (BIA+; Dijkstra & van Heuven, 2002), whereby the activation of semantic representations is delayed in L2 compared to L1 due to a lower subjective frequency of L2 items in unbalanced bilinguals (e.g., De Groot et al., 2002; Jankowiak et al., 2017). This has also been confirmed by ERP studies pointing to a delay in the N400 peak latency in L2 compared to L1 (e.g., van Heuven & Dijkstra, 2010; Jankowiak et al., 2017). Crucially, no

Table 4. Mean RTs with 95% CI (the Mood–Language–Word valence interaction).

Word valence	Positive mood		Negative mood	
	Polish (L1)	*English (L2)*	*Polish (L1)*	*English (L2)*
Negative	846.74 [219.65, 407.45]	890.72 [211.83, 467.07]	866.57 [235.67, 395.22]	910.24 [233.56, 443.12]
Neutral	984.33 [242.41, 499.5]	1,036.65 [266.55, 503.55]	1,002.31 [265.08, 472.15]	1,016.4 [261.92, 492.55]
Positive	821.53 [225.87, 369.79]	837.58 [217.72, 402.13]	825.8 [224.17, 377.47]	865.62 [235.78, 394.06]

RTs: reaction times; CI: confidence interval.

between-language temporal differences for neutral words in the negative mood condition accords with Clore and Huntsinger's (2007) observation that many findings in cognitive psychology (e.g., semantic priming, false memories, heuristic processing) are actually observed when participants are not in a negative mood, particularly with relation to neutral stimuli. Therefore, this study offers a novel contribution to research on bilingual language processing by pointing out that the predictions postulated within the interactive activation models might be mostly applicable to neutral word processing. Consequently, it seems crucial for studies on bilingual language processing to consider participants' emotional state as a potential confounding variable and to control it by collecting mood ratings and detailed information about the history of mood disorders.

Then, relying on substantial evidence showing facilitatory effects of both a positive mood (e.g., Chwilla et al., 2011) and positively laden words (e.g., Ponari et al., 2015), we believe that no between-language temporal differences for positive words in a positive mood observed here could result from the activation of a cumulative positivity-driven mechanism, leading to a strong processing advantage for both L1 and L2 words. Such an interpretation would also accord well with a monolingual ERP study conducted by Pratt and Kelly (2008), who observed enhanced amplitudes at around 400 ms to positive compared to negative words in a positive mood, with no such a difference in a negative mood, pointing to an enhanced comprehension of mood-congruent words, yet only in a positive mood.

Mood and gender

Another important question examined in this study was whether gender is a factor modulating an interaction between mood and language. We predicted that the response facilitation (as indexed by faster RTs) in a positive relative to negative mood would be stronger in females compared to males (e.g., Federmeier et al., 2001; Luomala & Laaksonen, 2000; Martin, 2003). Consistent with our hypothesis, we observed faster RTs to words in the positive compared to negative mood condition only in females, with no such a between-mood effect in males. Crucially, our exploratory analysis showed that this gender effect was not additionally modulated by language nativeness (i.e., the mood–gender interaction was observed irrespective of the language of operation).

The results observed for female participants are consistent with the Affect-as-information hypothesis (Clore & Huntsinger, 2007), whereby being in a positive mood leads to a broader cognitive flexibility, effortless integration of incoming information, and a global focus of attention (Gasper & Clore, 2002), which consequently leads to facilitated problem solving mechanisms (van Berkum et al., 2013). In contrast, a negative mood is strongly associated with extended inhibition of cognitive mechanisms engaged in information processing, as it is assumed to promote a ruminative style of thinking (Bar, 2009; Bolte et al., 2003). Similarly, such a processing advantage in a positive compared to negative mood also accords with previous research showing that, unlike a negative mood, a positive mood may exert facilitatory effects on different areas of language processing (e.g., Chwilla et al., 2011; Pinheiro et al., 2013; van Berkum et al., 2013). For instance, Chwilla et al. (2011) used neutral high and low cloze probability sentences (e.g., *The pillows are stuffed with feathers/books . . .*, respectively) and induced positive and negative moods via film clips in a sentence reading task. They reported greater N400 amplitude reduction for high cloze probability sentences when participants were in a negative compared to positive mood.

Interestingly, despite many methodological similarities (i.e., similar mood induction procedure, task, stimuli used, and participants' L2), our results for female participants differ from the behavioural results obtained by Kissler and Bromberek-Dyzman (2021), with the exception of a between-language difference that was observed in both studies (i.e., faster RTs to L1 compared to L2 words). Specifically, contrary to the processing advantage (i.e., faster RTs) of a positive mood observed here in females, in the study by Kissler and Bromberek-Dyzman (2021), German–English bilinguals responded faster to L1 than L2 words irrespectively of the mood polarity. They also observed a trend towards faster RTs to negative words in L2 than L1. The differences between the two studies may be attributed, among others, to a varying proportion of females to males (i.e., 78% of females in Kissler and Bromberek-Dyzman, 2021, and 50% here) and participants' dissimilar L2 proficiency levels (i.e., $M_{LexTALE}$=69.5% in Kissler and Bromberek-Dyzman, 2021; $M_{LexTALE}$=79.8% here). This may indicate that emotional responses to words in L1 and L2 may, among others, differ as a function of L2 proficiency, which is in line with previous research pointing to the crucial role of L2 proficiency in emotional responding (e.g., Costa et al., 2014; Harris et al., 2006).

Critically, the female advantage in a positive compared to negative mood observed here is consistent with the ERP study conducted by Federmeier et al. (2001), which first documented gender differences in positive and neutral mood effects on word processing. The researchers used sentence pairs (e.g., *They wanted to make the hotel look more like a tropical resort. So, along the driveway they planted rows of . . .*) ending with an expected word (e.g., *palms*), an unexpected word from the same semantic category (*a within-category violation*; e.g., *pines*), or from a different yet related semantic category (*a between-category violation*; e.g., *tulips*). In females, while N400 amplitudes in the neutral mood condition were the smallest for expected items and, then, smaller for within- compared to between-category violations, no changes in N400 amplitudes were observed between the two types of semantic violations in the positive mood condition. In contrast, in men, no differences in N400 amplitudes were observed between expected items, within-category violations, and between-category violations. These results point to a more profound role of mood in semantic processing in females than males, which could result from females' greater sensitivity to emotions (e.g., Goldstein et al., 2001; Tobin et al., 2000; Vrana & Rollock, 2002). Such a modulation by gender has also been previously reflected in higher arousal and greater heart rate deceleration to emotional films in females relative to males (e.g., Bianchin & Angrilli, 2012; Codispoti et al., 2008). Altogether, this study extends Federmeier et al.'s (2001) findings by demonstrating that gender may also modulate emotional word processing irrespective of language nativeness in unbalanced bilinguals experiencing positive and negative moods.

Interestingly, our results also indicated that the interaction between mood and gender in negative mood may be moderated by one's physiological arousal. Our results showed that an increase in arousal ratings in the negative mood condition was accompanied by faster RTs in females and slower RTs in males. Thus, although males have been observed to be better emotion-regulators than females (e.g., McRae et al., 2008), our results indicate that higher arousal in a negative mood may in fact facilitate language-related processes to a greater extent in females than in males. It is therefore vital that future research further explores potential systematic relationships between mood, gender, and different levels of physiological arousal, which would allow us to better understand gender-dependent differences in emotional reactivity and copying with affective disorders.

Word valence and gender

The final research question addressed in this study pertained to the relationship between gender and word valence. We predicted the response facilitation (as indexed by faster RTs) of positive and negative compared to neutral words (e.g., Chen et al., 2015; Opitz & Degner, 2012; Ponari et al., 2015) being more pronounced in females than males (e.g., Abbassi et al., 2019; Rodway et al., 2003; Van Strien & Van Beek, 2000). Although we observed the general processing advantage (i.e., faster RTs and higher accuracy) of both positive and negative over neutral words, the effect was comparably strong in both females and males. Positive words were also responded to faster than negative words irrespective of gender.

Such a gender-independent effect is consistent with previous research pointing to facilitatory mechanisms involved in emotional compared to neutral word processing in both L1 (e.g., Goh et al., 2016; Kissler & Herbert, 2013; Kousta et al., 2009; Vinson et al., 2014) and L2 (e.g., Conrad et al., 2011; Ferré et al., 2013; Grabovac & Pléh, 2014; Opitz & Degner, 2012; Ponari et al., 2015). For instance, in the study by Ponari et al. (2015), early and late bilingual speakers of 14 typologically different languages and native speakers of English showed slower lexical responses to neutral compared to emotional (positive and negative) words in their respective languages. Such results are typically attributed to the Motivated attention and affective states hypothesis (Lang & Bradley, 2013), whereby motivational relevance is modulated by emotional salience, such that negative stimuli evoke threat-related cognitive mechanisms, while positive stimuli elicit appetitive motivation systems that promote sustenance.

Moreover, the observed processing advantage of positive over negative words is also consistent with the Positivity offset hypothesis (e.g., Ito & Cacioppo, 2005), whereby positively laden verbal stimuli involve a higher informational density in the memory system and are therefore processed preferentially (i.e., as indexed by shorter RTs and more pronounced early posterior negativity [EPN] and late positivity complex [LPC] amplitudes relative to negative stimuli; see Kauschke et al., 2019 for a review). For instance, Bayer and Schacht (2014) observed larger EPN and LPC amplitudes as well as faster RTs to positive compared to negative words in a task involving silent reading and an occasional 1-back recognition test (i.e., deciding if a given stimulus and the one preceding it are the same), therefore indicating that positive word processing requires less cognitive effort compared to negative words.

Although previous research has suggested that females process emotional words faster than males due to their increased sensitivity towards the valence of emotional stimuli (e.g., Hofer et al., 2007; Rodway et al., 2003; Van Strien & Van Beek, 2000), the results observed in this study showed that both men and women can exhibit a comparable sensitivity to an affective value of language. One of the possible explanations is a limited nature of behavioural measures (e.g., RTs and accuracy rates), as previous research finding gender differences often adopted both behavioural and electrophysiological (*Electroencephalography* [EEG]) or functional Magnetic Resonance Imaging (fMRI) measures (e.g., Chentsova-Dutton & Tsai, 2007). This points to the importance of employing neurophysiological methods, such as EEG, which provides a continuous measure of the brain activity and, unlike behavioural measures, reflects a neurobiological response to a stimulus (Cohen, 2014).

Conclusion

This study tested mood effects on emotional word processing in L1 and L2, additionally accounting for gender differences. Our results revealed that the relationship between mood and language nativeness depended on word valence. The observed results suggest that the facilitatory effect of a positive mood and positive words may accumulate, mitigating response time differences between L1 and L2. This includes the temporal delay frequently observed in response to L2 relative to L1 (see Dijkstra & van Heuven, 2002) in unbalanced bilinguals, which may not be observed when bilinguals are in a negative mood. Future research should further explore if such findings can also be observed in broader communicative contexts (e.g., the sentence context) and beyond behavioural measures (e.g., using the EEG or fMRI measures).

In line with gendered perceptions of emotionality (McCormick et al., 2016), our study also revealed that though both females and males experienced comparable mood changes, only females' responses to isolated words were affected by mood, irrespective of the language of operation. Apart from linking this finding to greater emotional sensitivity in females than males (e.g., Bianchin & Angrilli, 2012), we suggest that it may be modulated by language proficiency and physiological arousal. Crucially, future research should go beyond identifying possible mediating factors, trying to account for such gendered perceptions of emotionality in the context of language processing. Researchers should now theorise about possible reasons behind such a gender-driven finding in the linguistic context by linking it to, for instance, how we define gender as a social construct (e.g., Winter, 2015), gender stereotypes (e.g., Plant et al., 2000), gendered power relationships (e.g., McCormick et al., 2016), or gender-based socialisation processes (e.g., Brody & Hall, 2008).

Acknowledgements

We would like to express our sincere gratitude to Guillaume Thierry, Aina Casaponsa, and Rafał Jończyk for their invaluable help.

Author contributions

M.N. contributed to study design, material preparation, experiment programming, data collection, data analyses, data visualisation, manuscript writing, editing, and reviewing. K.J. contributed to writing, editing, and reviewing the manuscript. K.B.D. contributed to study design and manuscript reviewing.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Polish National Centre for Research and Development under Grant POWR.03.02.00-00-I004/17-01.

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Supplemental material

Supplemental material for this article is available online.

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Appendix M: Research article 2 (Naranowicz et al. 2022b)

Naranowicz, Marcin, Katarzyna Jankowiak, Patrycja Kakuba, Katarzyna Bromberek-Dyzman and Guillaume Thierry. 2022. "In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages", *Brain Sciences* 12, 3: 316. doi: https://doi.org/10.3390/brainsci12030316.

brain sciences

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Article

In a Bilingual Mood: Mood Affects Lexico-Semantic Processing Differently in Native and Non-Native Languages

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Abstract: Positive and negative moods tend to have differential effects on lexico-semantic processing in the native language (L1). Though accumulating evidence points to dampened sensitivity to affective stimuli in the non-native language (L2), little is known about the effects of positive and negative moods on L2 processing. Here, we show that lexico-semantic processing is differently affected by positive and negative moods only in L1. Unbalanced Polish–English bilinguals made meaningfulness judgments on L1 and L2 sentences during two EEG recording sessions featuring either positive- or negative-mood-inducing films. We observed a reduced N1 (lexical processing) for negative compared to positive mood in L2 only, a reduced N2 (lexico-semantic processing) in negative compared to positive mood in L1 only, a reduced N400 (lexico-semantic processing) for meaningless compared to meaningful L1 sentences in positive mood only, and an enhanced late positive complex (semantic integration and re-analysis) for L2 compared to L1 meaningful sentence in negative mood only. Altogether, these results suggest that positive and negative moods affect lexical, lexico-semantic, and semantic processing differently in L1 and L2. Our observations are consistent with previous accounts of mood-dependent processing and emotion down-regulation observed in bilinguals.

Keywords: bilingualism; mood; lexico-semantic processing; emotion regulation; meaning integration; event-related potentials

Citation: Naranowicz, M.; Jankowiak, K.; Kakuba, P.; Bromberek-Dyzman, K.; Thierry, G. In a Bilingual Mood: Mood Affects Lexico-Semantic Processing Differently in Native and Non-Native Languages. *Brain Sci.* **2022**, *12*, 316. https://doi.org/10.3390/brainsci12030316

Academic Editor: Kenneth R. Paap

Received: 5 January 2022
Accepted: 23 February 2022
Published: 26 February 2022

1. Introduction

Affect (i.e., emotions, attitudes, feelings, and moods) permeates all aspects of human existence, including communicative interactions, oftentimes unobtrusively yet pervasively [1]. Seeing that 21st century communication is incrementally becoming international, with most people around the world speaking more than one language daily [2], it seems vital to shift research attention towards the relationship between affect and bilingualism. Unbalanced bilinguals, for instance, have frequently been observed to show dampened emotional sensitivity to non-native content (see [3] for a review). Interestingly, recent evidence has also shown that emotional word processing can also be affected by mood, a current affective background state [4,5]. However, mood effects on language comprehension in a broader communicative context in bilinguals have received little scholarly attention. The present study thus investigates potential differences in positive and negative mood effects on lexico-semantic processing in native (L1) and non-native (L2) languages.

1.1. Emotion Effects on Bilingualism

There is a growing interest in the relationship between affect and language nativeness, with emotion research showing both similarities and differences between L1 and L2 (see [3] for a review). However, recent evidence has more often pointed to dampened affective sensitivity in L2, especially in relation to negatively valenced content, as indexed by survey [6,7], behavioural [8,9], physiological [10,11], electrophysiological [12,13], and hemodynamic responses [14,15]. For instance, in an event-related potential (ERP) study, Jończyk et al. [13] observed a reduced N400 response to negative compared to positive L2 sentences and compared to positive and negative L1 sentences in immersed Polish–English bilinguals. Overall, such emotional detachment in L2 in unbalanced late bilinguals has been associated with learning L2 in an instructional (i.e., not immersive) environment [6], a late age of L2 acquisition combined with low L2 proficiency [16], and a weaker connection between lexico-semantic representations and affect in L2 due to infrequent use of emotional words [17].

Recent evidence has also shown that when emotionally evocative stimuli are not language-bound, bilinguals are able to implicitly down-regulate the magnitude of their emotional response more effectively in L2 than L1 [18,19]. For instance, Morawetz et al. [18] observed a more effective implicit emotion regulation through content labelling (i.e., choosing a noun semantically related to a presented picture) in participants' L2 (German) than in their L1 (English). Such results suggest that bilinguals can effectively activate automatic emotion regulatory strategies when using their L2. It remains an open question, however, whether L2 comprehension facilitates such regulation efforts to the same degree as L2 production.

1.2. Mood and Semantic Processes in L1

Mood has been defined as an unobtrusive, slowly changing, and low-intensity affective background state, fluctuating across time from feeling good (a positive mood) to feeling bad (a negative mood) [20]. Mood effects on language have been studied employing the N400 component: a negativity with a centro-parietal scalp distribution, peaking in amplitude at around 300–500 ms post stimulus onset [21]. It is often referred to as an anomaly detector; increased N400 amplitudes can, for instance, be evoked by critical words semantically incongruent with a sentence context [22]. Two other language-related ERP components have shown sensitivity to mood changes: N1 [4] and the late positive complex (LPC) [23]. N1 is a negativity peaking at around 100–200 ms post stimulus onset over parietal electrodes [24]. Besides being sensitive to word lexical characteristics (e.g., lexical frequency) [25], N1 amplitudes can also be altered when socially relevant feedback is anticipated [26] and by positive and negative moods [4]. LPC is a positive-going brainwave peaking at around 600–800 ms over centro-parietal electrodes [24]. An increase in LPC amplitude has been associated with more controlled, higher-level (cognitive) stimulus processing and the re-allocation of attentional, motivational, and evaluative resources [27].

Electrophysiological research on monolinguals has pointed to qualitatively different modulatory effects of positive and negative moods on semantic processes [1,23,28,29]. For instance, Chwilla et al. [23] presented participants with positive and negative film clips and asked them to read high-cloze (i.e., semantically correct) and low-cloze (i.e., semantically anomalous) sentences. They observed increased N400 amplitudes for low-cloze compared to high-cloze sentences in participants experiencing a positive mood, with the effect being restricted to the right hemisphere and left occipital and temporal sites in the negative mood condition. According to the authors, these results suggest that a positive and negative mood do not lead to quantitative differences in cognitive processing (e.g., a relative decrease in motivation or attention in a negative mood) but to qualitatively different lexico-semantic processing styles [28,29].

Furthermore, Pinheiro et al. [28] presented participants with positive, negative, and neutral pictures and asked them to make semantic judgements about sentence pairs ending in an (i) expected word, (ii) unexpected word of the same semantic category (i.e., within-category violation), and (iii) unexpected word from a different yet semantically related category (i.e., between-category violation). Whilst within-category violations resulted in a more pronounced N400 response to the negative mood condition, the positive mood condition evoked decreased N400 amplitudes, suggesting that negative and positive moods tend to weaken and strengthen, respectively, lexico-semantic access to words within a given semantic network. Crucially, the authors also found that expected items elicited attenuated N400 amplitudes in the negative compared to the positive mood condition, which points to an increased word expectancy in the negative mood condition, possibly due to a higher sensitivity to contextual information and more attention to detail.

1.3. Mood and Semantic Processes in L2

The modulation of language comprehension by mood has recently been studied in the bilingual context. Naranowicz et al. [5] asked unbalanced Polish–English bilinguals to watch positive and negative film clips and then classify single words as positive, negative, or neutral. Unlike males, females categorised the stimuli faster in a positive compared to negative mood. While there was no between-mood difference in response times to L1 positive words, participants responded faster to L2 positive words when they were in a positive compared to negative mood. Additionally, participants categorised neutral words faster in L1 than L2 in the positive mood condition only.

Similarly, Kissler and Bromberek-Dyzman [4] asked unbalanced German–English bilinguals to watch mood-inducing film clips and categorise decontextualised words as positive, negative, or neutral in an ERP study. They observed an attenuated left-lateralised N1 response to L1 words in the positive compared to the negative mood condition but no between-mood difference for L2 words, suggesting that the effects of mood on the early stage of word processing might be limited to L1. However, they found no mood–language interaction in either the N400 or the LCP time windows, which points to a possibly short-lived effect of mood induction in L1 and L2, at least in the case of single word processing. Altogether, bilingual research has shown that emotional word processing can be differently modulated by positive and negative moods, at least at the initial stages of individual word processing. To our knowledge, there is no tangible evidence to date regarding the effect of positive and negative moods on L1 and L2 semantic processing in a sentential context.

1.4. Research Aims and Hypotheses

The present study aimed to determine whether and how positive and negative moods modulate lexico-semantic processing in unbalanced Polish–English bilinguals. To test this, we instructed participants to watch positive- and negative-mood-inducing animated film clips and make semantic decisions on L1 and L2 sentences while their electroencephalographic (EEG) activity was being recorded.

Building upon previous research, we expected to observe a classic N400 modulation by sentence meaningfulness, with more pronounced N400 amplitudes for meaningless than meaningful sentences (e.g., "These houses were transformed into country lobsters/mansions permanently.") in both L1 and L2 [22]. We also hypothesised that while N400 amplitude would be differently modulated by positive and negative moods in L1 (i.e., N400 amplitudes elicited by meaningful sentences would be reduced in a negative relative to positive mood) [28,30], L2 processing would be less sensitive to mood manipulation.

In addition to regulatory effects of mood on lexico-semantic processing indexed by N400 modulations [23,28,29], emerging evidence suggests that positive and negative moods also affect other language processing stages such as lexical processing (indexed by changes in N1 responses) [4] and semantic re-evaluation (indexed by changes in LPC responses) [4,23]. Therefore, to better understand the complexity of mood effects on bilingual language processing, we exploratorily analysed four additional ERP components marking its other stages: P1 (i.e., indexing perceptual processing), N1 (i.e., indexing lexical processing), N2 (i.e., indexing lexico-semantic processing), and LPC (i.e., indexing semantic integration and re-evaluation).

2. Materials and Methods

2.1. Participants

Thirty Polish–English (L1–L2) bilinguals participated in the study. Four datasets had to be excluded from the analyses due to low quality of the recorded EEG signal. As arousal may affect mood effects on language processing [5], four further datasets were excluded on the basis of exceptionally low arousal ratings (i.e., a decrease/no change in arousal post- relative to pre-experiment) to match the arousal level between the positive and negative mood conditions. The final sample thus consisted of 22 participants aged 22–32 (M_{Age} = 25.91, 95% CI (24.74, 27.08)), who were graduate students of English Studies at Adam Mickiewicz University, Poznań, engaged in an intensive English-only curriculum (the C2 level of the Common European Framework of Reference, CEFR). Due to gender-driven mood effects on language processing observed in previous research [5], only females participated in the present study. Consistent with de Groot [31], participants were classified as highly proficient unbalanced late Polish–English bilinguals who had not lived in the L2 (English) environment and had acquired their L2 in an instructional yet immersive learning context (see Table 1). All participants were in a good general affective state, reporting low degrees of depression, anxiety, and stress around the time of data collection (see Table 2). All participants had normal/corrected-to-normal vision and hearing and no neurological, mood, or language disorders. Personality-wise, participants were characterised as somewhat extraverted, emotionally stable, and highly agreeable, conscientious, and open to new experiences (see Table 2). They also reported being able to empathise with others, including fictitious characters (see Table 2) [1]. For their participation, they received a gift card of 300 PLN.

Table 1. Participants' sociolinguistic data (means with 95% CI).

	Polish (L1)	English (L2)
Proficiency [1]	n/a	91.33 (88.94, 93.72)
Proficiency [2]	96.87 (94.91, 98.82)	90.13 (87.55, 92.71)
Dominance [2]	57.63 (55.56, 59.71)	55.63 (52.60, 58.66)
Immersion [2]	70.67 (65.81, 75.52)	69.10 (65.38, 72.82)
Age of acquisition [2]	n/a	7.70 (6.50, 8.89)
Years of learning [2]	n/a	17.53 (15.77, 19.30)
Frequency of expressing emotions [2]	5.18 (4.70, 5.66)	4.14 (3.64, 4.63)

[1] Based on the LexTALE test (the standardised LexTALE score) [32]. [2] Based on the language history questionnaire 3.0 (LHQ [33], as translated into Polish by Naranowicz and Witczak): the proficiency, dominance, and immersion scores (percentages), age of acquisition and years of use (years), and frequency of expressing emotions (1—never, 7—always).

2.2. Linguistic Stimuli

The linguistic stimuli consisted of 90 Polish and 90 English concrete emotionally-neutral nouns (see Table 3 for details on their lexico-semantic properties) embedded in a sentence mid-position of 90 constraining sentence frames in each language. Each sentence frame was used twice, once each with a semantically congruent and incongruent critical word (e.g., "These houses were transformed into country mansions/lobsters permanently."), which summed up to 360 unique sentences (see at https://osf.io/e3r28/ (accessed on 25 February 2022)).

All sentences were of 8–10 words (M = 9.00, 95% CI (8.88, 9.12) for both Polish and English items), declarative, emotionally neutral, highly constraining, and devoid of personal references (to avoid a self-positivity bias [47]). The critical words were presented as the seventh word of a sentence. To avoid possible processing strategies due to the fixed sentence position of the critical words, we constructed 60 Polish and 60 English filler sentences containing a semantically incongruent item as the eighth/ninth/tenth word. This yielded a final set of 480 sentences, half of which were presented during the first experimental session and half of which were presented during the second experimental session. The meaningful and meaningless sentences with the same critical word were not presented during the same experimental session.

Table 2. Participants' characteristics (mean percentages with 95% CI).

Positive affect [1]	63.70 (58.87, 68.54)	Agreeableness [5]	81.80 (78.76, 84.84)
Negative affect [1]	42.73 (39.73, 45.72)	Conscientiousness [5]	72.87 (66.25, 79.48)
Handedness [2]	81.10 (63.19, 99.01)	Neuroticism [5]	57.60 (50.88, 64.31)
Empathy [3]	46.47 (42.75, 50.19)	Openness to experience [5]	77.00 (73.62, 80.38)
Depression [4]	7.73 (5.61, 9.86)	Perspective-taking [6]	68.45 (61.07, 75.83)
Anxiety [4]	9.30 (6.27, 12.33)	Fantasy scale [6]	70.95 (62.19, 79.72)
Stress [4]	5.23 (2.81, 7.65)	Empathetic concern [6]	77.50 (72.03, 82.97)
Extraversion [5]	62.53 (55.84, 69.22)	Personal distress [6]	49.76 (45.53, 53.99)

[1] Based on the Positive and Negative Affect Schedule (PANAS [34], as translated into Polish by Fajkowska and Marszał-Wiśniewska [35]): positive affect (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive, and active) and negative affect (distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid). [2] Based on the handedness questionnaire [36] (as adapted from Oldfield [37]): left-handedness (−100–−28), ambidexterity (−29–48), and right-handedness (48–100). [3] Based on the Empathy Quotient [38] (as translated into Polish by Wainaina-Woźna): low (0–39%), average (40–64%), above average (65–78%), and high (79–100%) levels of empathy. [4] Based on the DASS-21 [39] (as 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. [5] Based on the Big Five Inventory [40] (as translated into Polish by Strus et al. [41]): extraversion (talkativeness, activity, assertiveness vs. silence, passivity, reserve), agreeableness (kindness, trust, warmth vs. hostility, selfishness, distrust), conscientiousness (organisation, thoroughness, reliability vs. carelessness, negligence, unreliability), neuroticism (nervousness, moodiness, temperamentality vs. confidence, resilience), and openness to experience (imagination, curiosity, creativity vs. shallowness, imperceptiveness). [6] Based on the Interpersonal Reactivity Index [42] (as translated into Polish by Kaźmierczak et al. [43]): perspective-taking scale ("the tendency to spontaneously adopt the psychological point of view of others"), fantasy scale (one's "tendencies to transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies, and plays"), empathetic concern scale ("other-oriented feelings of sympathy and concern for unfortunate others"), and personal distress scale ("self-oriented feelings of personal anxiety and unease in tense interpersonal settings").

Table 3. The lexico-semantic properties of the critical words (means with 95% CI).

	Frequency [1]	Word Valence [2]	Arousal [3]	Concreteness [4]	Syllables [5]	Letters [6]
Polish (L1)	3.39 (3.32, 3.47)	4.36 (4.29, 4.42)	2.07 (2.00, 2.15)	6.59 (6.54, 6.65)	2.47 (2.36, 2.57)	6.93 (6.73, 7.14)
English (L2)	3.81 (3.72, 3.90)	4.43 (4.35, 4.50)	2.19 (2.11, 2.26)	6.43 (6.36, 6.51)	2.23 (2.14, 2.32)	7.27 (7.05, 7.48)

[1] Based on SUBTLEX-UK [44] and SUBTLEX-PL [45] (the Zipf scale): 1—the lowest frequency, 7—the highest frequency. [2] Based on a norming study: 1—the word evokes strongly negative emotions, 7—the word evokes strongly positive emotions. [3] Based on a norming study: 1—the word makes me feel completely unaroused, 7—the word makes me feel highly aroused. [4] Based on a norming study: 1—the word is abstract, 7—the word is concrete. [5] Range = 2–4 syllables. [6] Range = 6–8 letters. Excluded words: Polish–English translation equivalents, polysemous words, cognates, and interlanguage homonyms and homographs (see [46]).

All the sentences were rated in a norming study on their meaningfulness (i.e., meaningfulness ratings), the probability of encountering them in everyday communicative interactions (i.e., the probability ratings), and the emotional value of each sentence frame (i.e., the valence ratings; see Table 4 for details on raters). All the ratings were analysed with a linear mixed-effects model (LMM) [48–51], using the lme4 package (Version 1.1-23) [52] for R (R Development Core Team, 2020, Vienna, Austria). Sum contrasts were applied to all categorical factors. A maximal model was first computed with a full random-effect structure, including subject- and item-related variance components for intercepts and by-subject and by-item random slopes for fixed effects [49]. 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 [53]. 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 LMM (the lmerTest package, Version 3.1.2.) [54] for R (R Development Core Team, 2020, Vienna, Austria). Post-hoc analyses were calculated using the emmeans package (Version 1.7.0) [55] for R (R Development Core Team, 2020, Vienna, Austria).

Table 4. Participants' characteristics—all normative tests (means with 95% CI).

	Film Clips	**Critical Words**	**Sentences**	
Participants	50 Polish–English bilinguals (30/film clip)	121 Polish–English bilinguals (30/word)	325 Polish–English bilinguals (25/sentence)	210 English native speakers (30/sentence)
Gender [1]	F: 50, M: 0, NB: 0	F: 101, M: 20, NB: 0	F: 259, M: 63, NB: 3	F: 121, M: 79, NB: 10
Age [2]	21.19 (20.62, 21.76)	23.69 (23.36, 24.01)	20.69 (20.16, 21.22)	23.47 (20.85, 26.09)
L1 Proficiency [3]	6.91 (6.80, 7.00)	6.84 (6.71, 6.98)	6.81 (6.60, 7.00)	6.88 (6.75, 7.00)
L2 Proficiency [3]	5.44 (5.20, 5.68)	5.25 (4.96, 5.54)	5.43 (5.20, 5.69)	4.03 (3.49, 4.57)
Years of L2 learning [2]	14.06 (12.83, 15.30)	15.75 (14.80, 16.70)	14.06 (13.02, 15.10)	8.81 (6.11, 11.51)

[1] F—female, M—male, NB—non-binary. [2] The score in years. [3] Based on self-reported proficiency: 1—beginner, 7—native speaker.

The analysis performed on the meaningful ratings showed a fixed effect of sentence type, b = 4.76, SE = 0.08, t(69.62) = 56.93, p < 0.001, such that meaningful sentences were rated as more meaningful than meaningless sentences (see Table 4). There was also a fixed effect of language, b = 0.18, SE = 0.08, t(72.10) = 2.28, p = 0.026, whereby English sentences were rated as more meaningful than Polish sentences (see Table 4). The analysis also revealed a language × sentence type interaction, b = −0.39, SE = 0.16 t(69.93) = −2.35, p = 0.022. Post-hoc comparisons showed that while meaningless English relative to Polish sentences scored higher on meaningfulness, b = 0.37, SE = 0.13, t(65.60) = 2.81, p = 0.039, there was no such between-language difference for meaningful sentences, b = −0.01, SE = 0.09, t(84.20) = −0.16, p = 1.00 (see Table 4). Similarly, the analysis performed on the probability ratings yielded a fixed effect of sentence type, b = 4.13, SE = 0.08, t(96.87) = 48.46, p < 0.001, such that meaningful sentences were rated as more probable to be encountered in everyday interactions compared to meaningless sentences (see Table 4). There was also a fixed effect of language, b = 0.40, SE = 0.10, t(84.38) = 4.13, p < 0.001, whereby English sentences were rated as being more probable to be encountered in everyday interactions than Polish sentences (see Table 4). The analysis also revealed a language × sentence type interaction, b = 0.83, SE = 0.17, t(97.71) = 4.93, p < 0.001. Post-hoc comparisons showed that while English meaningful sentences scores higher on predictability, b = 0.81, SE = 0.16, t(73.70) = 5.10, p < 0.001, there was no such between-language difference for meaningless sentences, b = −0.02, SE = 0.09, t(190.60) = −0.24, p = 1.00 (see Table 4). Finally, there was no between-language difference for the valence ratings, b = 0.03, SE = 0.07, t(152.21) = 0.41, p = 0.686 (see Table 5).

Table 5. Results of the norming study on the experimental sentences (means with 95% CI).

	Meaningfulness [1]		**Probability of Encountering [2]**		**Valence [3]**	
	Polish (L1)	English (L2)	Polish (L1)	English (L2)	Polish (L1)	English (L2)
Meaningful	6.43 (6.39, 6.47)	6.41 (6.38, 6.45)	5.25 (5.19, 5.32)	6.06 (6.01, 6.12)	4.09 (4.03, 4.16)	4.18 (4.11, 4.25)
Meaningless	1.50 (1.46, 1.54)	1.87 (1.83, 1.92)	1.49 (1.47, 1.52)	1.47 (1.44, 1.51)		

[1] Based on a norming study: 1—totally meaningless, 7—totally meaningful. [2] Based on a norming study: 1—totally improbable, 7—totally probable. [3] Based on a norming study: 1—strongly negative, 7—strongly positive; to enable the assessment of the neutrality of the constructed sentence frames, 30 strongly positive and 30 strongly negative sentences adapted from Jończyk et al. [13] were used as filler sentences in each language.

2.3. Mood-Inducing Stimuli

To induce a positive or negative mood in our participants, we employed 28 affectively evocative animated film clips of 90 s each adapted from Naranowicz et al. [5]. The clips contained no spoken or written words to avoid a possible priming effect of language. In total, participants watched 21 min of such an audio–video material during each experimental session. Each clip was rated in a norming study (see Table 4 for details on raters) on mood valence (1—the film evokes strongly negative emotions, 7—the film evokes strongly positive emotions) and arousal (1—the film makes me feel completely unaroused, 7—the film makes me feel highly aroused). Fourteen clips with the highest and lowest valence were then used as the ones inducing a positive mood ($M_{Valence}$ = 5.34, 95% CI (5.17, 5.52); $M_{Arousal}$ = 3.62, 95% CI (3.06, 4.17)) and a negative mood ($M_{Valence}$ = 1.97, 95% CI (1.78, 2.16); $M_{Arousal}$ = 4.27, 95% CI (3.94, 4.59)), respectively. The ratings were analysed with a linear mixed-effects model (LMM) [48–51], using the lme4 package (version 1.1–23) [52] for R (R Development Core Team, 2020, Vienna, Austria). The analysis of the mood valence ratings yielded a fixed effect of film type, $b = -3.37$, SE = 0.18, $t(47.30) = -18.92$, $p < 0.001$, whereby the film clips selected to induce a positive mood were rated higher in valence than those selected to induce a negative mood ($M_{PositiveMood}$ = 5.34, 95% CI (5.17, 5.52); $M_{NegativeMood}$ = 1.97, 95% CI (1.78, 2.16)), $t(20.98) = -24.94$, $p < 0.001$. Then, the analysis of the arousal ratings showed no difference between the two film types in terms of how arousing they were ($M_{PositiveMood}$ = 3.62, 95% CI (3.06, 4.17); $M_{NegativeMood}$ = 4.27, 95% CI (3.94, 4.59)), $b = 0.65$, SE = 0.41, $t(38.40) = 1.57$, $p = 0.124$.

2.4. Procedure

The procedure applied in the experiment was approved by the Ethics Committee for Research Involving Human Participants at Adam Mickiewicz University, Poznań. The experiment was conducted at the Neuroscience of Language Laboratory (Faculty of English, Adam Mickiewicz University, Poznań). Potential participants were initially screened by means of an online version of DASS-21 [39], the PANAS test [34], and an additional medical history questionnaire.

Each of the two sessions (conducted one week apart) involved either a positive or negative mood induction (counterbalanced order). Participants were seated in a dimly lit and quiet booth, 75 cm away from a LED monitor with a screen resolution of 1280 × 1024 pixels. All remaining questionnaires (see Tables 1 and 2) were administered during EEG cap preparation to build participants' linguistic and socio-biographical profiles. E-prime 3.0 software was used to present the stimuli and collect the behavioural data, and BrainVision Recorder 1.23 (Gilching, Germany) was used to collect the EEG data.

Participants were asked to rate their mood prior to and post mood manipulation based on the mood valence and arousal ratings and the Polish version of PANAS [34]. Participants first watched three film clips to induce the targeted mood and were instructed to put themselves in the targeted mood [56], to imagine that they were one of the protagonists, and to sympathise with other characters [57]. Participants performed a semantic decision task, wherein they decided whether a sentence was meaningless or meaningful by pressing corresponding keys (counterbalanced order and key designation). Another film clip was presented every 20 sentences (counterbalanced order) to sustain the targeted mood. Participants completed one Polish and one English block within each session (counterbalanced order), each comprising 45 meaningful, 45 meaningless, and 30 filler (meaningless) sentences. The time sequence of stimulus presentation is provided in Figure 1.

2.5. EEG Data Recording

EEG signals were recorded from 64 active actiCAP slim electrodes (Brain Products), placed at the standard extended 10–20 positions with the ground placed at Fpz. The bipolar electrodes monitoring vertical (vEOG) and horizontal (hEOG) eye movements were placed above and below the left eye and next to the outer rims of both eyes, respectively. EEG signal was recorded using BrainVision actiCHamp amplifiers (Brain Products, Gilching, Germany), sampled at 500 Hz/channel, and referenced to the Fz electrode. Impedances were kept below 10 kΩ for each electrode. ERPs were time-locked to the onset of the seventh (critical) word of each sentence.

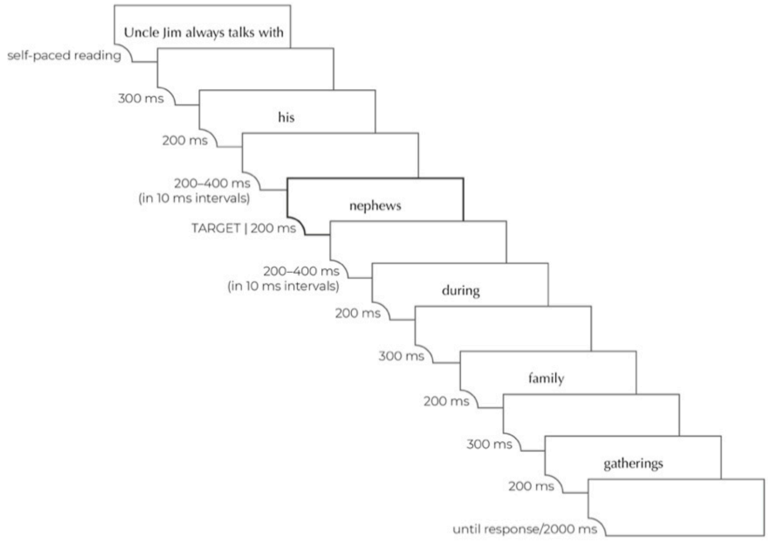

Figure 1. Time sequence of stimulus presentation.

2.6. Behavioural Data Analysis

All analyses were performed in the R environment (Version 4.0; R Development Core Team, 2020, Vienna, Austria). Participants rated their mood on 7-point mood valence and arousal scales, similarly to the norming study (see the Mood-Inducing Stimuli section for details), and a Polish version of PANAS [34], employing a 5-point Likert scale (1 —very slightly or not at all, 5 —extremely) with 10 positive adjectives (i.e., positive affect scores) and 10 negative adjectives (i.e., negative affect scores; see Table 2). Then, the positive and negative affect scores were summed separately and presented as a proportion of the summed positive to negative affect scores. All adjectives had feminine forms. Mood ratings were analysed using linear mixed-effects modelling (LMM), with the lme4 package (Version 1.1-23) for R (R Development Core Team, 2020, Vienna, Austria) [52] (see the Linguistic Stimuli section for details), on the basis of a 2 (time of testing: pre-experiment vs. post-experiment) × 2 (film type: positive vs. negative) within-subject design. To ensure the effectiveness of our mood manipulation, we compared mood valence, arousal, and PANAS ratings post- relative to pre-experiment separately in each mood condition as planned comparisons, predicting an increase/no change in mood ratings in the positive mood condition and a decrease in the negative mood condition.

Response accuracy data were analysed with a generalised linear mixed-effects model (GLMM; i.e., logistic regression) [48–51], using the lme4 package (Version 1.1-23) [52] for R (R Development Core Team, 2020, Vienna, Austria), on the basis of a 2 (language: Polish vs. English) × 2 (mood: positive vs. negative) × 2 (sentence type: meaningful vs. meaningless) within-subject design (see the Linguistic Stimuli section for details).

2.7. Electrophysiological Data Analysis

We analysed two ERP components previously reported to be modulated by semantic anomalies [58], language of operation [13], and mood [23]: the N400 (300–500 ms) and LPC (600–800 ms). Both components were analysed over 9 electrodes: FC1, FCz, FC2 (fronto-central), C1, Cz, C2 (central), CP1, CPz, and CP2 (centro-parietal) [12,13]. Moreover, as Kissler and Bromberek-Dyzman [4] observed early modulatory effects of mood on bilingual word processing, we exploratorily analysed the P1 (70–130 ms), N1 (170–230 ms), and N2 (250–350 ms) components previously linked to the pre-lexical (P1), lexical (N1), and lexico-semantic (N2) stages of language processing, whose time windows were selected based on visual inspection of the averaged ERPs and of electrodes at maximal peak amplitude. P1 and N1 were analysed over 4 electrodes: PO7, PO8 (parieto-occipital), P7, and P8 (parietal), whereas N2 was analysed over 6 electrodes: F1, Fz, F2 (frontal), FC1, FCz, and FC2 (fronto-central).

BrainVision Analyzer 2.1 software (Brain Products, Gilching, Germany) was used to analyse the data offline. Continuous EEG data were re-referenced to the common average reference [24,59], filtered offline (Butterworth zero-phase filter) with a high-pass cut-off set at 0.1 Hz (slope 24 dB/octave) and a low-pass cut-off set at 20 Hz (slope 24 dB/octave) and then epoched from 200 ms before critical word onset to 1500 ms afterwards. Then, the data were baseline-corrected relative to signal between −200 and 0 ms before stimulus onset and edited for artifacts (i.e., rejecting trials with flat lines at 0 μV and rejecting trials with voltage differences higher than 100 μV or voltage steps higher than 50 μV). Ocular artifacts were corrected using the ocular artifact regression method proposed by Gratton and Coles [60].

Mean P1, N1, and N2 amplitudes were analysed using RM ANOVAs on the basis of a 2 (language: Polish vs. English) × 2 (mood: positive vs. negative) × 2 (sentence type: meaningful vs. meaningless) within-subject design. Mean N400 and LPC amplitudes were analysed using RM ANOVAs on the basis of a 2 (language: Polish vs. English) × 2 (mood: positive vs. negative) × 2 (sentence type: meaningful vs. meaningless) × 3 (laterality: left-lateral vs. medial vs. right-lateral) × 3 (electrode position: anterior vs. central vs. posterior) within-subject design. In all analyses, pairwise comparisons were Bonferroni corrected. Greenhouse–Geisser correction was applied when the sphericity assumption was violated.

Moreover, Pearson correlation coefficients (r) were calculated to further explore whether there was a linear relationship between the observed effects and participants' mood ratings along with their linguistic (see Table 1) and personality-based characteristics (see Table 2). All R scripts and full model specifications can be found at https://osf.io/e3r28/ (accessed on 25 February 2022).

3. Results

3.1. Self-Report Data: Mood Ratings

The analysis performed on the mood valence ratings showed fixed effects of both film type, $b = 1.21$, SE = 0.16, $t(63) = 7.68$, $p < 0.001$, and testing time, $b = -0.89$, SE = 0.16, $t(63) = -5.65$, $p < 0.001$, along with a film type × testing time interaction, $b = 3.41$, SE = 0.31, $t(63) = 10.86$, $p < 0.001$. As expected, planned comparisons showed an increase in valence ratings in post- compared to pre-experiment mood ratings in the positive mood condition, $b = 0.82$, SE = 0.22, $t(63) = 3.69$, $p = 0.003$, and a decrease in the negative mood condition, $b = -2.59$, SE = 0.22, $t(63) = -11.68$, $p < 0.001$ (see Figure 2 and Table 6). Similarly, the analysis of the PANAS ratings revealed fixed effects of both film type, $b = 0.39$, SE = 0.08, $t(63) = 4.97$, $p < 0.001$, and testing time, $b = -0.31$, SE = 0.08, $t(63) = -3.86$, $p < 0.001$, along with a film type × testing time interaction, $b = 1.23$, SE = 0.16, $t(63) = 7.75$, $p < 0.001$. Planned comparisons showed an increase in the PANAS ratings between pre- and post-experiment in the positive mood condition, $b = 0.31$, SE = 0.11, $t(63) = 2.75$, $p = 0.047$, and a decrease in the negative mood condition, $b = -0.70$, SE = 0.11, $t(63) = -6.25$, $p < 0.001$ (see Figure 2 and Table 6). The analysis of the arousal ratings showed only one main effect of testing time, $b = 0.50$, SE = 0.20, $t(63) = 2.55$, $p = 0.013$, such that participants felt more emotionally aroused after the experiment than before it began, regardless of mood type (see Figure 2 and Table 6).

Additional correlational analyses revealed that mood valence ratings correlated positively with the Interpersonal Reactivity Index [42] empathetic concern scores in a positive mood, $r = 0.43$, 95% CI (0.02, 0.72), $t(21) = 2.18$, $p = 0.041$, as well as negatively with the DASS-21 [39] depression scores in a negative mood, $r = -0.41$, 95% CI (−0.71, −0.01), $t(21) = -2.25$, $p = 0.049$. Then, the analyses also indicated that participants' arousal level in a negative mood correlated negatively with their familiarity with the mood-inducing film clips, $r = -0.43$, 95% CI (−0.72, −0.02), $t(21) = -2.19$, $p = 0.040$, as well as positively with the Interpersonal Reactivity Index [42] empathetic concern scores, $r = -0.49$, 95% CI (0.10, 0.75), $t(21) = 2.59$, $p = 0.017$.

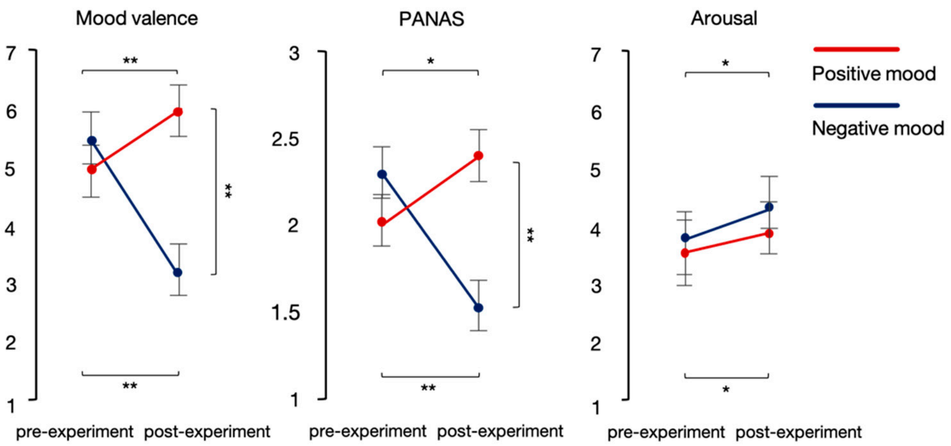

Figure 2. Mood ratings for the mood valence scale (**left**), the PANAS (**middle**), and the arousal scale (**right**) with CI of 95% (** $p < 0.001$, * $p < 0.01$).

Table 6. Mood Ratings from PANAS and the mood valence and arousal Scales (with 95% CI).

	Mood Valence	PANAS	Arousal
	Positive mood condition		
Pre-experiment	5.14 (4.79, 5.48)	2.08 (1.83, 2.33)	3.50 (2.96, 4.04)
Post-experiment	5.95 (5.61, 6.30)	2.46 (2.21, 2.72)	3.86 (3.32, 4.40)
	Negative mood condition		
Pre-experiment	5.64 (5.29, 5.98)	2.33 (2.08, 2.59)	3.73 (3.19, 4.27)
Post-experiment	3.05 (2.70, 3.39)	1.40 (1.14, 1.65)	4.36 (3.82, 4.90)

3.2. Behavioural Data: Response Accuracy

The analysis performed on response accuracy showed a fixed effect of language, $b = -0.59$, SE = 0.25, $z = -2.32$, $p = 0.020$, whereby Polish (L1) sentences (M = 97.44%, 95% CI (90.69, 100.00)) were responded to with greater accuracy than English (L2) sentences (M = 95.80%, 95% CI (87.22, 100.00)). The analysis also yielded a fixed effect of sentence type, $b = -0.77$, SE = 0.32, $z = -2.41$, $p = 0.016$, such that meaningless sentences (M = 97.16%, 95% CI (90.06, 100.00)) were responded to with greater accuracy than meaningful sentences (M = 96.14%, 95% CI (87.90, 100.00)).

The analysis also revealed a mood × sentence type interaction, $b = 1.13$, SE = 0.50, $z = 2.28$, $p = 0.023$. Post-hoc comparisons showed that while meaningless relative to meaningful sentences were responded to with greater accuracy in the negative mood, ($M_{Meaningful}$ = 95.68%, 95% CI (86.99, 100.00); $M_{Meaningless}$ = 97.19%, 95% CI (90.11, 100.00)), $b = -1.33$, SE = .46, $z = -2.92$, $p = 0.021$, there was no such between-sentence-type difference in the positive mood ($M_{Meaningful}$ = 96.59%, 95% CI (88.82, 100.00); $M_{Meaningless}$ = 97.14%, 95% CI (90.01, 100.00)), $b = -0.20$, SE = 0.34 $z = -0.58$, $p = 0.99$. All the remaining differences in response accuracy were non-significant, *p*s > 0.05.

3.3. Electrophysiological Data

3.3.1. P1 Time Window (70–130 ms)

The RM ANOVA performed within the P1 time window (70–130 ms) showed a main effect of language, $F(1, 21) = 10.36$, $p = 0.004$, $\eta_p^2 = 0.330$, whereby P1 amplitudes were more pronounced in response to English (L2) relative to Polish (L1) sentences. There was also a main effect of mood, $F(1, 21) = 4.51$, $p = 0.046$, $\eta_p^2 = 0.177$, such that P1 amplitudes were larger in the positive as compared to the negative mood condition. All the remaining differences in P1 mean amplitudes were non-significant, *p*s > 0.05.

Moreover, a correlational analysis indicated that the P1 mood effect (i.e., the difference in P1 amplitudes between a positive and negative mood) correlated positively with the

Empathy Quotient scores [38], $r = 0.49$, 95% CI (0.10, 0.75), $t(21) = 2.56$, $p = 0.018$ (see Figure 3).

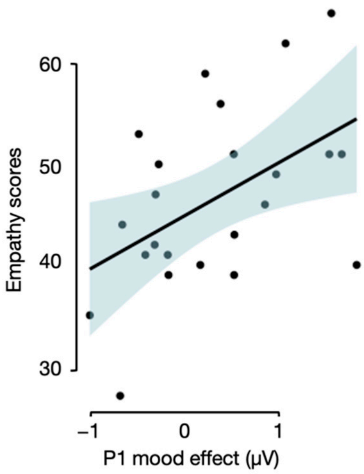

Figure 3. A correlation plot depicting the relationship between the P1 mood effect and participants' empathy level.

3.3.2. N1 Time Window (170–230 ms)

The RM *ANOVA* performed within the N1 time window (170–230 ms) showed a main effect of language, $F(1, 21) = 10.04$, $p = 0.005$, $\eta_p^2 = 0.332$, whereby English (L2) sentences elicited a more pronounced N1 response compared to Polish (L1) sentences.

We also found a language × sentence type interaction, $F(1, 21) = 5.49$, $p = 0.029$, $\eta_p^2 = 0.207$. Post-hoc paired sample *t*-tests showed that while English (L2) meaningless sentences elicited a more pronounced N1 response compared to Polish (L1) meaningless sentences, $t(21) = -4.44$, $p < 0.001$, there was no such between-language difference for meaningful sentences, $t(21) = -1.69$, $p = 0.105$.

Crucially, the analysis also showed a language × mood interaction, $F(1, 21) = 8.11$, $p = 0.010$, $\eta_p^2 = 0.279$. Post-hoc paired sample *t*-tests showed that while English (L2) sentences elicited a more pronounced N1 response in the positive compared to negative mood condition, $t(21) = -2.66$, $p = 0.015$, the analysis showed no such between-mood difference for Polish (L1) sentences, $t(21) = 1.39$, $p = 0.180$ (see Figures 4 and 5). All the remaining differences in N1 mean amplitudes were non-significant, *p*s > 0.05.

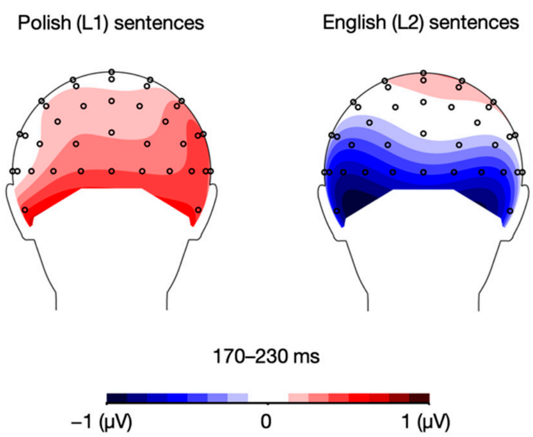

Figure 4. Topographic distribution of the difference between ERP amplitudes in the positive and negative mood conditions for Polish (L1) and English (L2) sentences in the 170–230 ms time window.

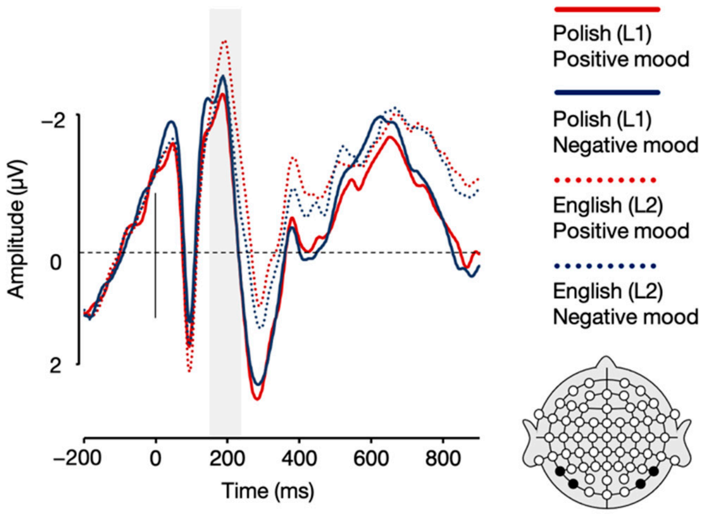

Figure 5. Grand averages for Polish (L1) and English (L2) sentences in the positive and negative mood conditions over parietal (P7, P8) and parieto-occipital (PO7, PO8) electrodes.

3.3.3. N2 Time Window (250–350 ms)

The RM *ANOVA* performed within the N2 time frame (250–350 ms) showed a main effect of sentence type, $F(1, 21) = 25.62$, $p < 0.001$, $\eta_p^2 = 0.550$, whereby meaningless sentences elicited larger N2 amplitudes than meaningful sentences. There was also a main effect of language, $F(1, 21) = 46.07$, $p < 0.001$, $\eta_p^2 = 0.687$, such that Polish (L1) sentences elicited more pronounced N2 amplitudes than English (L2) sentences. The analysis also revealed a main effect of mood, $F(1, 21) = 5.47$, $p = 0.029$, $\eta_p^2 = 0.207$, whereby the N2 amplitudes were more pronounced in the positive than the negative mood condition.

Importantly, the analysis also revealed a language × mood interaction, $F(1, 21) = 4.96$, $p = 0.037$, $\eta_p^2 = 0.191$. Post-hoc paired sample *t*-tests showed that while Polish (L1) sentences elicited a more pronounced N2 response in the positive compared to the negative mood condition, $t(21) = –2.89$, $p = 0.009$, whereas no such between-mood significant difference was found for English (L2) sentences, $t(21) = –0.59$, $p = 0.561$ (see Figures 6 and 7). All the remaining differences in N2 mean amplitudes were non-significant, *p*s > 0.05.

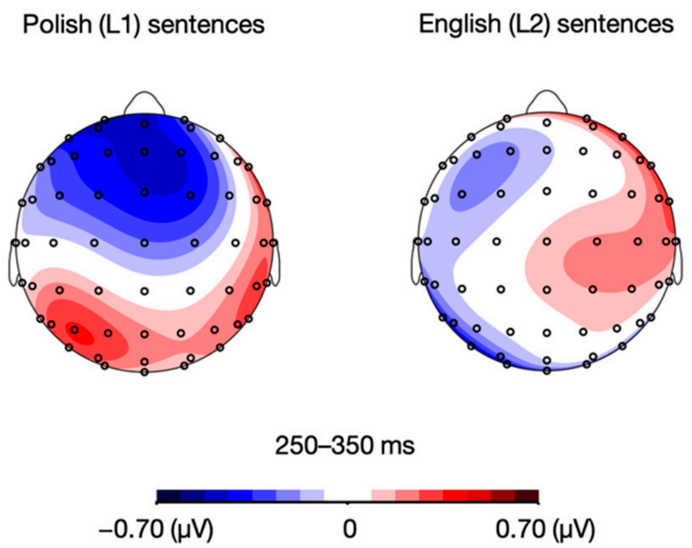

Figure 6. Topographic distribution of the ERP amplitude difference between positive and negative mood conditions for Polish (L1) and English (L2) sentences in the 250–350 ms time window.

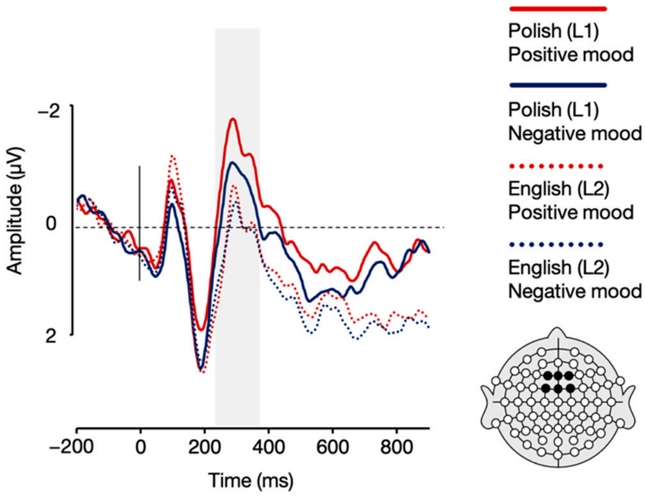

Figure 7. Grand average ERPs for Polish (L1) and English (L2) sentences in the positive and negative mood conditions over frontal (F1, Fz, F2) and fronto-central (FC1, FCz, FC2) electrodes.

3.3.4. N400 Time Window (300–500 ms)

The RM *ANOVA* performed within the N400 time frame (300–500 ms) showed a main effect of sentence type, $F(1, 21) = 39.28$, $p < 0.001$, $\eta_p^2 = 0.582$, such that the N400 amplitudes were more pronounced in response to meaningless than meaningful sentences.

The analysis also yielded a mood × language × sentence type × electrode position interaction, $F(2, 42) = 3.57$, $p = 0.048$, $\eta_p^2 = 0.145$, $\varepsilon = 0.769$. To deconstruct it, we conducted language × sentence type × electrode position post-hoc ANOVAs separately for each mood. The analyses showed a significant main effect of sentence type, with more robust N400 amplitudes for meaningless relative to meaningful sentences in both Polish (L1), $F(1, 21) = 15.72$, $p < 0.001$, $\eta_p^2 = 0.428$, and English, $F(1, 21) = 29.36$, $p < 0.001$, $\eta_p^2 = 0.583$.

Then, unlike for the negative mood condition, the analyses for the positive mood condition showed a language × sentence type × electrode position interaction, $F(2, 42) = 6.41$, $p = 0.012$, $\eta_p^2 = 0.234$, $\varepsilon = 0.642$. It was further deconstructed via language × sentence type post-hoc *ANOVA*s conducted separately for fronto-central (FC1, FCz, and FC2), central (C1, Cz, and C2), and centro-parietal (CP1, CPz, and CP2) electrodes. We observed the main effect of sentence type over fronto-central, $F(1, 21) = 11.35$, $p = 0.003$, $\eta_p^2 = 0.351$, central, $F(1, 21) = 16.24$, $p < 0.001$, $\eta_p^2 = 0.436$, and centro-parietal electrodes, $F(1, 21) = 10.30$, $p = 0.004$, $\eta_p^2 = 0.329$, whereby meaningless sentences evoked more pronounced N400 amplitudes compared to meaningful utterances in the positive mood condition.

Importantly, the analyses for the positive mood condition also revealed a language × sentence type interaction over centro-parietal electrodes, $F(1, 21) = 6.67$, $p = 0.017$, $\eta_p^2 = 0.241$. Post-hoc paired sample *t*-tests showed that in a positive mood, while English (L2) meaningless sentences evoked higher N400 amplitudes relative to meaningful sentences, $t(21) = 3.70$, $p = 0.001$, there was no such between-sentence-type difference for Polish (L1) sentences, $t(21) = 1.46$, $p = 0.160$. Additionally, the post-hoc *t*-tests also revealed attenuated N400 amplitudes for Polish (L1) compared to English (L2) meaningless sentences in the positive mood condition, $t(21) = -2.40$, $p = 0.026$, with no such between-language difference for meaningful sentences, $t(21) = 0.10$, $p = 0.919$ (see Figures 8 and 9). All the remaining differences in N400 mean amplitudes were non-significant, *p*s > 0.05.

3.3.5. LPC Time Window (600–800 ms)

The RM *ANOVA* performed within the LPC time frame (600–800 ms) showed a main effect of sentence type, $F(1, 21) = 27.68$, $p < 0.001$, $\eta_p^2 = 0.569$, such that meaningless sentences elicited increased positivity relative to meaningful sentences. The analysis also yielded a main effect of language, $F(1, 21) = 4.34$, $p = 0.050$, $\eta_p^2 = 0.171$, whereby English (L2) sentences elicited a more pronounced LPC response than Polish (L1) sentences.

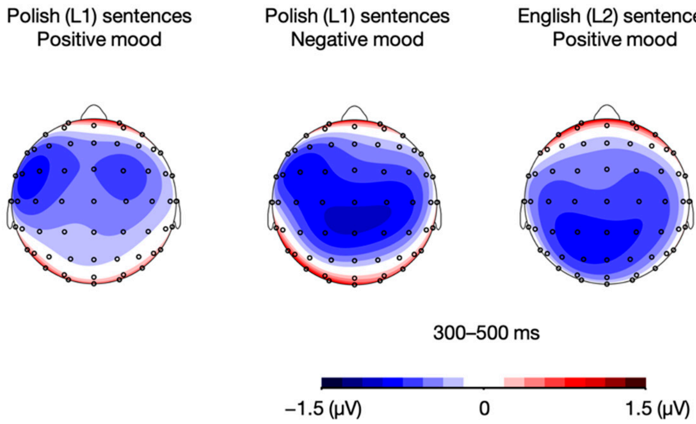

Figure 8. Topographic distribution of the difference between ERP amplitudes in the meaningful and meaningless conditions for Polish (L1) and English (L2) sentences in the positive and negative mood conditions in the 300–500 ms time window.

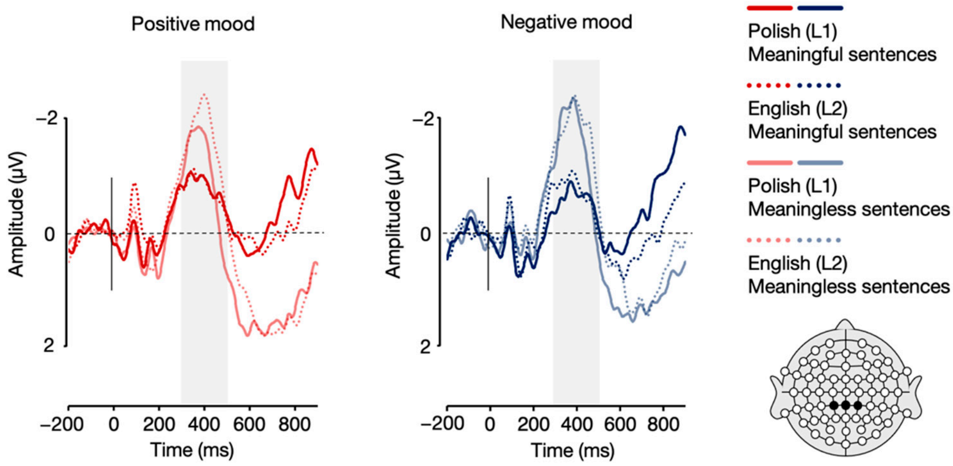

Figure 9. Grand averages for Polish (L1) and English (L2) meaningful and meaningless sentences in the positive and negative mood conditions over centro-parietal (CP1, CPz, CP2) electrodes.

We also found a language × sentence type interaction, $F(1, 21) = 5.49$, $p = 0.029$, $\eta_p^2 = 0.207$. Post-hoc paired sample *t*-tests showed that while English (L2) meaningful sentences elicited a more pronounced LPC response compared to Polish (L1) meaningful sentences, $t(21) = 2.99$, $p = 0.007$, there was no such between-language difference for meaningless sentences, $t(21) = 0.87$, $p = 0.395$.

The analyses also showed a mood × language × sentence type interaction, $F(1, 21) = 4.98$, $p = 0.037$, $\eta_p^2 = 0.192$. To deconstruct it, we performed language × sentence type post-hoc ANOVAs separately for each mood. The analyses showed a significant main effect of sentence type in both the positive mood condition, $F(1, 21) = 32.62$, $p < 0.001$, $\eta_p^2 = 0.608$, and the negative mood condition, $F(1, 21) = 29.36$, $p < 0.001$, $\eta_p^2 = 0.583$.

Then, unlike in the positive mood condition, the analysis for the negative mood condition yielded a language × sentence type interaction, $F(1, 21) = 6.78$, $p = 0.017$, $\eta_p^2 = 0.244$. Post-hoc paired sample *t*-tests performed for the negative mood condition showed between-language differences for meaningful sentences, with an attenuated LPC response to Polish (L1) relative to English (L2) meaningful utterances, $t(21) = 3.37$, $p = 0.003$. However, such a between-language difference was not found for meaningless sentences, $t(21) = -0.07$, $p = 0.948$ (see Figures 10 and 11). All the remaining differences in LPC mean that amplitudes were non-significant, $ps > 0.05$.

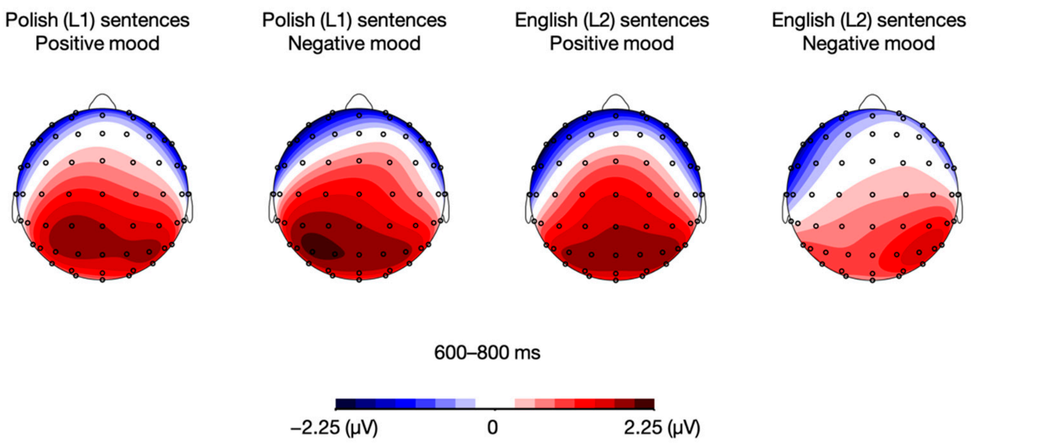

Figure 10. Topographic distribution of the difference between ERP amplitudes in the meaningful and meaningless conditions for Polish (L1) and English (L2) sentences in the positive and negative mood conditions in the 600–800 ms time window.

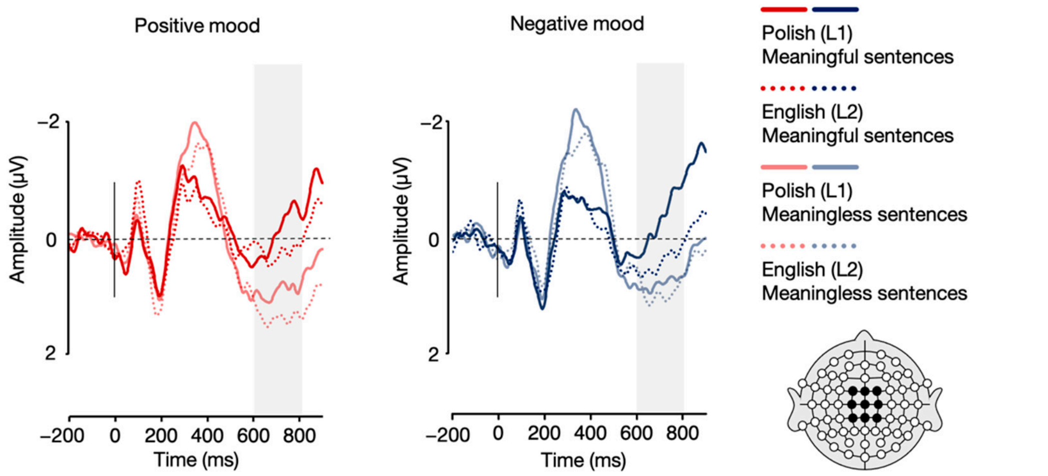

Figure 11. Grand averages for Polish (L1) and English (L2) meaningful and meaningless sentences in the positive and negative mood conditions over fronto-central (FC1, FCz, FC2), central (C1, Cz, C2), and centro-parietal (CP1, CPz, CP2) electrodes.

4. Discussion

The present study investigated how positive and negative moods modulate lexico-semantic processing (as indexed by N400 responses) in L1 and L2 of unbalanced Polish–English (L1–L2) bilinguals. Besides a classic N400 modulation by meaningfulness [22], we expected to observe an N400 effect of meaningfulness to be differently modulated by mood in L1 and L2, as suggested by recent evidence pointing to the activation of narrowed and detailed-oriented cognitive processing in a negative mood in L1 [28], reduced sensitivity to emotional content in L2 compared to L1 [6–15,61,62], and more effective emotion regulation processes in bilinguals operating in L2 relative to L1 [18]. In order to thoroughly analyse mood effects on bilingual language processing, we also exploratorily analysed other language-related ERP components: P1 (i.e., a marker of pre-lexical perceptual processing), N1 (i.e., a marker of lexical processing), N2 (i.e., a marker of lexico-semantic processing), and LPC (i.e., a marker of semantic re-analysis and integration).

4.1. Perceptual Processing: P1

The P1 component has been considered an index of perceptual processing of stimuli (including linguistic ones), reflecting early sensory processing in the visual modality that are modulated by attention [25]. Consequently, P1 has also been employed to investigate mood effects on attention (see [63] for a review). Here, we observed larger P1 amplitudes in a positive compared to a negative mood, consistent with research pointing to increased attentional focus in a positive relative to a negative mood [63–65]. For instance, in a flanker task (i.e., differentiating between strings with identical and incompatible letters), Moriya and Nittono [63] observed a larger probe-evoked P1 response in a positive relative to a negative mood induced by affective pictures. They suggested that the broadened attentional scope in a positive mood reflects the brain activity in the extrastriate visual cortices, which are responsible for early visual attention [66]. Interestingly, our correlational analysis also pointed to the strength of the P1 mood effect increasing proportionally to empathy level, suggesting that an increase in empathy may lead to an increase in mood's effects on perception and attention regulation.

We also found more robust P1 amplitudes in response to L2 than L1. Previous research has shown that the P1 can also be modulated by participants' arousal level. For instance, Vogel and Luck [67] manipulated the difficulty of a perceptual task to increase participants' physiological arousal and reported larger P1 amplitudes in highly compared to moderately aroused participants. A similarly difficulty-driven mechanism might have been elicited in our participants, and thus modulations within the P1 response might reflect increased difficulty (and hence arousal) due to the performance of a cognitive task testing our participants' comprehension of their less proficient and less dominant language. Such an interpretation is also in line with previous research that has typically pointed to less automatic and more cognitively taxing mechanisms in L2 [68].

4.2. Lexical Processing: N1

The visual N1 component is typically responsive to lexical attributes of words (e.g., word frequency) in word recognition tasks and is thus interpreted as an index of lexical processing (see [69] for a review). Here, we observed larger N1 responses to English (L2) than Polish (L1) words, and this effect was further modulated by mood. N1 amplitudes evoked by words in L2 sentences were reduced in a negative relative to a positive mood, and between-mood difference was not significant in L1. Our results could therefore be explained by lexical processing being comparably easy in both moods in L1, with a negative mood facilitating it in L2. Such an interpretation is consistent with research demonstrating that a negative mood can prompt a more accommodative processing mode, thus improving deception [70] and linguistic ambiguity detection [71]. Research has also shown that a negative mood can trigger behavioural, cognitive, and motivational strategies to cope with a demanding situation, activating analytic problem solving as a neural response to a potential threat [72,73]. Therefore, despite leading to unpleasant experiences, a negative mood may increase engagement in the stimuli and motivation for deeper processing when operating in L2, which results in a more effective lexical search.

Similarly, Kissler and Bromberek-Dyzman [4] found an enhanced left-lateralised N1 response to L1 words in a positive compared to negative mood, with no between-mood differences in L2. Following Schindler et al. [26], they proposed that mood may be treated as a relevant social communicative context for early word processing. Though we observed the N1 modulation by mood in the present study, its direction was inconsistent with the one observed by Kissler and Bromberek-Dyzman [4], which may be accounted for by the following differences in experimental procedures: while Kissler and Bromberek-Dyzman [4] used decontextualised positive, negative, and neutral words and asked participants to perform an emotive decision task (i.e., decide if a word is positive, negative, or neutral), our participants read neutral context-rich sentences and performed a semantic decision task. Additionally, judging by the LexTALE [32] results, the German–English bilinguals tested in the study conducted by Kissler and Bromberek-Dyzman [4] were less proficient in their L2 (English; $M_{LexTALE}$ = 69.5%; the B2 level of CEFR) compared to our participants ($M_{LexTALE}$ = 91.3%; the C1/C2 level of CEFR), which suggests that L2 proficiency may be another factor influencing early mood effects on language. Therefore, to provide further insights into the role of mood in lexical processing, future research could employ linguistic stimuli presented in a richer context and focus on bilinguals' L2 proficiency.

Additionally, N1 amplitude was increased for meaningless compared to meaningful sentences in L2. As N1 is also sensitive to systematic patterns (e.g., stimulus repetition) [24], the observed effect seems to suggest that participants implicitly anticipated an aberrant word to be presented as the seventh word, despite our having included filler sentences. As in the case of P1, such repetition effect may relate to greater cognitive demands, consistent with lower interconnectivity between lexical and semantic representations in L2 [74].

4.3. Lexico-Semantic and Semantic Processing: N2 and N400

Similarly to N1, N2 modulations have been linked to lexical processing [74,75], particularly to inhibitory processes (indexing, e.g., conflict resolution) activated during the selection of an appropriate lexical item [76]. L2 research has also shown that N2 responses can reflect lexical processing somewhat overlapping with early lexico-semantic processing [77]. Here, we observed larger N2 amplitudes for meaningless compared to meaningful sentences, suggesting that semantic information might have been accessed early in the processing stream, possibly due to anticipation. Consistent with Proverbio et al.'s [69] findings, such an effect may result from the activation of early anticipatory processes prompted by the highly constraining sentential context, especially given that the N2 modulation appeared to carry over to the N400 time window.

We also found larger N2 amplitudes for Polish (L1) than English (L2) sentences, an effect in the opposite direction to the one observed in the P1 and N1 time windows. This could reflect less automatic activation of lexical-level representations in L2, given that the subjective frequency of L2 items is lower than that of L1 items in unbalanced bilinguals [78], in turn affecting levels of activation in the semantic network (see the spreading activation model [79]). Such an effect also discards the idea that L1 may have required more cognitive resources during this intermediate stage of language processing, potentially due to greater activation of lexical-level representations in the dominant language (i.e., L1).

As in the N1 window, we found larger N2 amplitudes in a positive compared to a negative mood, suggesting that mood effects continue to affect L1 and L2 processing in the window of lexico-semantic processing. Crucially, we also observed an attenuated N2 response to Polish (L1) sentences in a negative compared to positive mood, with no between-mood difference for English (L2) sentences. Interestingly, this mood effect on language during lexico-semantic processing appears to be a mirror reflection of the one observed during lexical processing (i.e., in the N1 range). Our interpretation of this reversal is that a negative mood may activate detail-oriented processing when a given language requires more cognitive resources, e.g., L2 during lexical processing (modulating N1) and L1 during early lexico-semantic processing (modulating N2).

We also observed modulations within the N400 time frame. N400 has been associated with lexico-semantic processing, as this component is sensitive to semantic anomalies of different types [21,22]. Here, while N400 amplitudes were more pronounced in response to English (L2) meaningless relative to meaningful sentences in both a positive and negative mood, such an effect occurred only in a negative mood for L1 processing (note that the interaction between language and sentence time found in the N1 time window (170–230 ms) most likely disappeared in the N2 time window (250–350 ms) due to systematic stimulus repetition, suggesting that effects occurring in later time windows were not carry-over effects of earlier differences). First, an attenuation of the N400 response to Polish (L1) meaningless relative to meaningful sentences in a positive mood is consistent with previous studies pointing to facilitatory effects of a positive mood on lexico-semantic processing [23,28,29,80,81]. For instance, Wang et al. [80] explored how positive and negative moods affect the processing of question–answer pairs, manipulating their semantic congruity (i.e., whether critical words were semantically congruent with the question context) and task relevance (i.e., whether critical words were relevant to questions or not). They observed that while incongruent relative to congruent words elicited larger N400 amplitudes regardless of task relevance in a negative mood, such an N400 congruity effect was observed only for task-relevant words in a positive mood. They proposed that while language users in a positive mood seem to allocate their attentional resources to the most relevant contextual information, a negative mood may trigger non-selective and analytical information processing, directing equal attention to semantic relations among all words, regardless of whether they are critical to a given context or not. Moreover, given the functional interpretation of N400 modulations in language processing (see [82] for a review), our results may relate to a positive mood requiring fewer cognitive resources than a negative mood when information is being retrieved from long-term memory during sentence comprehension. Such an interpretation is also consistent with previous evidence supporting the affect-as-information hypothesis [83], whereby positive and negative moods are thought to promote qualitatively different information processing styles. A positive mood is often associated with effortless integration of incoming information and associative, heuristics-based thinking. In contrast, a negative mood typically implies extended inhibition of cognitive mechanisms engaged in information processing and ruminative thinking (see [20] for a review).

However, our results did not reveal an N400 modulation by mood that we predicted based on Pinheiro et al. [28]: an attenuated N400 response to meaningful sentences in a negative relative to positive mood. Instead, our results seem to concur with another result obtained by Pinheiro et al. [28]: an attenuation of the N400 response to within-category (i.e., unexpected word of the same semantic category) relative to between-category (i.e., unexpected word of a different semantic category) violations in the positive mood condition, together with a more pronounced N400 response to within-category violations relative to expected words in the negative mood condition. According to Pinheiro et al. [28], one interpretation is that moods may differently modulate the gradient of connections among different words in semantic memory, with a positive mood strengthening and a negative mood weakening them. Thus, participants in the present study might have perceived the critical words embedded in sentences as contextually unexpected yet not entirely meaningless, resembling the mechanisms engaged when processing within-category violations instead of the anticipated between-category violations.

Critically, consistent with our hypothesis, we observed differential effects of positive and negative moods on L1 processing only, with no mood effects for L2 processing. Additionally, the N400 response to meaningless sentences was reduced for L1 relative to L2 processing in a positive mood. Such results suggest that lexico-semantic processing in L2 may be more impervious to the effect of mood. This interpretation is consistent with recent evidence pointing to more effective implicit emotion regulation in L2 than L1. For instance, Morawetz et al. [18] observed that German–English bilinguals involuntarily displayed more effective emotion regulation mechanisms when presented with aversive pictures during L2 than L1 production. However, the L2 advantage disappeared when emotion regulation was explicitly invited through cognitive re-appraisal, suggesting that operating in L2 tends to activate regulatory mechanisms when emotional processing is spontaneous and implicit. Similarly, in the present study, participants read neutral L1 and L2 sentences and performed a semantic decision task, which did not explicitly require the activation of emotion regulation mechanisms. Therefore, we argue that increased emotion regulatory mechanisms triggered by L2 extend beyond L2 production [18], as our results suggest they are also active during L2 comprehension. This interpretation is in line with recent hemodynamic studies of bilingual speakers pointing to greater involvement of the amygdala (i.e., a subcortical structure ubiquitously involved in emotion processing and reinforcement) in L1 compared to L2 processing [84]. In sum, the N400 findings reported here suggest a decreased sensitivity to mood manipulation when unbalanced bilinguals process written content in L2 compared to L1.

4.4. Late Semantic Processing: LPC

LPC modulations have been linked to semantic integration and re-analysis, as well as the re-allocation of attentional, motivational, and evaluative resources [27]. Here, LPC mean amplitudes were greater for meaningful sentences in L2 than in L1 in the negative mood condition only. Consistent with our N400 effects (pointing to a dampened sensitivity to mood in L2) and previous evidence showing reduced emotional reactivity to L2 negative content [10,12,13], we propose that L2 processing triggers regulatory mechanisms protecting unbalanced bilinguals from adverse cognitive effects of a negative mood. Jończyk et al. [13], for instance, asked proficient immersed Polish–English bilinguals to assess the meaningfulness of L1 and L2 sentences ending in either affectively and semantically congruent or incongruent adjectives. They reported greater LPC amplitudes for L2 as compared to L1 negative sentences, a pattern very similar to that observed here in relation to mood manipulation. As originally proposed by Wu and Thierry [12], such an effect may relate to cognitive prevention, involuntarily activating a suppression mechanism upon encountering a potentially upsetting stimulus in L2, thereby inhibiting the full activation spread through the semantic network. This, in turn, would trigger re-evaluation mechanisms assessing the inhibited stimulus and engage memory-updating mechanisms. The same cognitive mechanisms could thus be triggered in our participants, with a negative mood context failing to modulate L2 sentence comprehension in the N400 range but nevertheless triggering re-evaluation processes to a greater extent in L2 than L1.

4.5. Response Accuracy

We observed equally accurate semantic judgements for meaningless and meaningful sentences in a positive mood, while meaningless relative to meaningful sentences were still identified more accurately in a negative mood. This supports the possibility that a positive mood led to more effective semantic judgements irrespective of the language of operation. Consistent with Wang et al. [81] and our electrophysiological data, such results suggest that a positive mood may prioritise the most important contextual information, at least when making rather cognitively untaxing semantic judgements.

4.6. Mood Manipulation

Consistently using an integrative approach to measure mood changes (see [85] for a review), we supplemented self-reported mood valence and arousal ratings (i.e., bipolar dimensions) with the results of PANAS [34], built on two unipolar dimensions of the positive affect (PA) and the negative affect (NA). Both mood valence and the PA/NA ratio consistently indicated that participants were responsive to mood manipulation, thus proving the affective evocativeness of the presented animated film clips. Interestingly, our correlational analyses also revealed that one's susceptibility to positive mood manipulation may increase proportionally to their empathy level. A similar pattern was observed here for perceptual processing, as indexed by P1 responses.

5. Conclusions

Altogether, we found differential language-driven mood effects in four consecutive stages of bilingual word processing within a sentence context: lexical processing (as indexed by N1), lexico-semantic processing (as indexed by both N2 and N400), and semantic integration and re-analysis (as indexed by LPC). We argue that a negative mood may activate detail-oriented processing affecting lexical search in the language of operation requiring more attentional resources. We also propose that the between-language differences observed in the N400 and LPC ranges point to the activation of emotion regulation [18] and suppression [12] mechanisms during L2 processing, offering a form of cognitive protection against potentially disruptive effects of a negative mood. Our findings might have important implications for everyday situations, especially those conducive to negative moods (e.g., counselling or judiciary proceedings). Indeed, in such circumstances, operating in L2 might prove a useful emotion regulation strategy for bilinguals. This idea is consistent with clinical research showing that discussing traumatic experiences in L2 allows bilingual speakers to emotionally distance themselves from them [86].

Author Contributions: Conceptualization, M.N., K.J., K.B.-D. and G.T.; methodology, M.N., K.J., K.B.-D. and G.T.; software: M.N.; validation, M.N. and K.J.; formal analysis, M.N. and K.J.; investigation, M.N., K.J. and P.K.; resources, M.N.; data curation, M.N., K.J. and P.K.; writing—original draft preparation, M.N. and K.J.; writing—review and editing, M.N., K.J., P.K, K.B.-D. and G.T.; visualization, M.N.; supervision, K.B.-D. and G.T.; project administration, M.N.; funding acquisition, M.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Science Centre in Poland, grant number 2018/31/N/HS2/00120. G.T. is supported by the Polish National Agency for Academic Exchange (NAWA) under the NAWA Chair Programme (PPN/PRO/2020/1/00006).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee for Research Involving Human Participants at Adam Mickiewicz University, Poznań (protocol 34/2019/2020, approved on 3 February 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The EEG data collected and analysed for the purpose of the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Appendix N: Research article 3 (Jankowiak et al. 2022)

Jankowiak, Katarzyna, Marcin Naranowicz and Guillaume Thierry. 2022. "Positive and negative moods differently affect creative meaning processing in both the native and non-native language", *Brain and Language* 235: 105188. doi: https://doi.org/10.1016/j.bandl.2022.105188.

Brain & Language 235 (2022) 105188

Contents lists available at ScienceDirect

Brain and Language

journal homepage: www.elsevier.com/locate/b&l

Positive and negative moods differently affect creative meaning processing in both the native and non-native language

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ARTICLE INFO

Keywords:
Bilingualism
Mood
Novel metaphor
Event-related potentials
N400
Late positive complex

ABSTRACT

Previous research has shown that positive and negative moods differently modulate lexico-semantic processes. However, little is known about effects of mood on creative meaning comprehension in bilinguals. Here, Polish–English (L1–L2) female bilinguals made meaningfulness judgments on L1 and L2 novel metaphoric, literal, and anomalous sentences during an EEG session featuring positive and negative mood induction. While novel metaphors elicited comparable event-related potential responses to anomalous sentences in the N400 time frame indexing lexico-semantic processing, the former evoked smaller amplitudes than the anomalous condition in the late positive complex (LPC) window, marking meaning re-evaluation. Also, the LPC responses to the three sentence types all converged when participants were in a negative mood, indicating that a negative mood, unlike a positive one, inhibits reliance on general knowledge structures and leads to more detail-oriented processing of semantically complex meanings in both L1 and L2.

1. Introduction

Mood, conceptualized as a slowly changing affective background state of low intensity that oscillates from feeling good (i.e., a positive mood) to feeling bad (i.e., a negative mood), unobtrusively tunes the dynamics of human behavior (see Forgas, 2017 for a review). Accumulating electrophysiological evidence has demonstrated that positive and negative moods may also differently regulate various cognitive mechanisms, including those engaged in language comprehension, activating broad and heuristics-based processing of semantic information in a positive mood and a narrow and detail-oriented one in a negative mood (e.g., Pinheiro et al., 2013; Vissers et al., 2013; Wang et al., 2016). Recently, interactions between mood and language processing have also been investigated in the bilingual context (Kissler & Bromberek-Dyzman, 2021; Naranowicz et al., 2022a,b). Yet, electrophysiological research has not yet explored how positive and negative moods affect creative meaning processing, and whether these mechanisms may be modulated by language of operation. Such research could provide valuable insights into mood-driven modulations of complex semantic processes engaged in metaphor comprehension, which entails extensive conceptual mapping mechanisms required to construct a new meaning in both the native (L1) and non-native (L2) language. The present study is the first to test whether and how bilinguals' current affective states impacts mechanisms engaged in creative meaning processing.

Previous event-related potential (ERP) research on the interplay between mood and semantic processing has reported modulations within the N400 range (e.g., Federmeier et al., 2001; Chwilla et al., 2011; Pinheiro et al., 2013). The N400 is a negative-going wave that peaks in amplitude at around 400 ms after stimulus onset. It is usually maximal over centroparietal electrode positions and indexes the amount of information retrieved from long-term memory (Kutas & Federmeier, 2000, 2011). Consequently, N400 modulations by mood provide insights into how positive and negative moods influence lexico-semantic processing. For instance, Pinheiro et al. (2013) observed that, in a baseline condition, closely related yet unexpected items (e.g., *The books were set aside for her by a teacher.*) elicited an increased N400 response relative to expected words (e.g., …*librarian.*) and decreased relative to unrelated words (e.g., …*dentist.*). Crucially, the processing of such closely related yet unexpected items was modulated by mood: the N400 response to these items resembled the response elicited by distantly related items in a negative mood and by expected items in a positive mood. Such results suggest that a positive mood enhances and a negative mood hinders lexico-semantic processing of words of varying semantic

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https://doi.org/10.1016/j.bandl.2022.105188
Received 14 April 2022; Received in revised form 21 September 2022; Accepted 29 September 2022

relatedness, respectively, strengthening and weakening the connections between them in semantic memory. Interestingly, Pinheiro et al. (2013) also found highly expected linguistic stimuli to elicit attenuated N400 amplitudes in a negative relative to a positive mood. According to Pinheiro et al. (2013), this suggests an increased word expectancy effect in a negative mood, potentially due to a closer attention to detail. Others, however, have failed to observe mood-driven differences in the N400 time frame, which may be linked to the lexico-semantic mechanisms of interest (i.e., semantic plausibility vs expectancy; Vissers et al., 2013) and the level of language processing (i.e., single-word vs sentence levels; Ogawa & Nittono, 2019).

Another semantics-related component sensitive to mood changes is the late positive complex (LPC; Chwilla et al., 2011; Vissers et al., 2013): a positive-going brainwave peaking in amplitude at around 600–800 ms after the stimulus onset (Luck, 2014), reflecting meaning re-analysis or additional working memory load (e.g., Brouwer et al., 2012; Regel et al., 2011; Spotorno et al., 2013). For instance, Vissers et al. (2013) found a robust LPC plausibility effect (i.e., higher LPC amplitudes evoked by semantically implausible relative to plausible sentences) in a positive but not negative mood, suggesting that semantic re-analysis processes might be mood-dependent (Schwarz & Clore, 1983).

Altogether, previous ERP studies on the role of mood in semantic processing are consistent with cognitive psychology research suggesting that a positive mood enables effortless integration of incoming information and leads to associative thinking (see Forgas, 2017 for a review). A negative mood, on the other hand, inhibits reliance on heuristics and leads to accommodative thinking (e.g., Bolte et al., 2003; Forgas, 2018). Consequently, while language processing might be more automatic in a positive mood, it may be more analytical and detail-oriented in a negative mood.

Accumulating evidence on the interplay between mood and semantic processing may also provide insights into research on affect and bilingualism (e.g., Morawetz et al., 2017; Thoma, 2021; Naranowicz et al., 2022a,b). Previous empirical studies have repeatedly shown decreased sensitivity to the affective value of the presented stimulus in L2 relative to L1 (e.g., Chen et al., 2015; Hsu et al., 2015; Jankowiak & Korpal, 2018; see Jankowiak, 2021 for a review), especially in the case of negatively-valenced content (Jończyk et al., 2016). Such findings concur with the assumption that bilinguals may implicitly down-regulate their emotional response in a different manner depending on whether they are in an L1 or L2 context (Morawetz et al., 2017). Recently, research on the affect–bilingualism interactions has been extended to the role of mood in bilingual language processing (Kissler & Bromberek-Dyzman, 2021; Naranowicz et al., 2022a,b). For instance, Naranowicz et al. (2022b) observed a reduced N400 response to meaningless sentences in L1 relative to L2 in a positive mood only, followed by larger LPC amplitudes for meaningful sentences in L2 relative to L1 in a negative but not a positive mood. These between-language differences in the N400 and LPC time windows extend previous research, potentially pointing to the activation of implicit emotion-regulation mechanisms, not only during L2 production (e.g., Morawetz et al., 2017), but also in L2 comprehension. At the same time, this pattern is suggestive of reduced emotional sensitivity for negative L2 content processing (e.g., Wu & Thierry, 2012), also evinced when unbalanced bilinguals operate in a negative mood. More research on emotion regulation strategies and decreased emotional reactivity in an L2 context is still needed in order to understand the underlying mechanisms behind such differential mood effects in bilinguals.

Previous neurophysiological studies on the role of mood in semantic processing have, however, mostly focused on the processing of semantically meaningful and meaningless stimuli (e.g., Chwilla et al., 2011; Vissers et al., 2013; Naranowicz et al., 2022b). They have not yet been extended to semantically complex language that features creative meaning, such as that conveyed by novel metaphors, though. Novel metaphors are defined as unfamiliar and creative meanings, whose comprehension requires extended cross-domain mapping mechanisms that include recognizing features common to two distinct concepts and enable new meaning creation (Gibbs & Colston, 2006, 2012). The complexity of these mechanisms is reflected in ERP patterns, whereby a graded effect is often observed, with the largest modulations recorded within the N400 and LPC time windows elicited by anomalous sentences, followed by novel metaphors, and finally literal meaning (e.g., Tang et al., 2017a,b; Jankowiak et al., 2021). Such a graded effects suggests a progressive decrease in cognitive load. Importantly, processing creative meaning also entails the employment of more complex response strategies, as participants are more likely to search for a possible meaning of presented stimuli in the presence of novel metaphors compared to the experiments employing only two levels of a sentence type (meaningful vs meaningless sentences). Crucially, experiments conducted thus far have not accounted for the role of mood in either monolingual or bilingual creative meaning processing, and it therefore remains under-investigated whether participants' mood can modulate brain responses to creative meaning conveyed by novel metaphoric sentences.

The present ERP study aims to determine whether and how mood modulates creative meaning processing (i.e., novel metaphor processing) in unbalanced bilingual speakers. To address this research question, we elicited positive and negative moods with animated films in Polish–English bilinguals and asked them to make semantic judgements on L1 and L2 novel metaphoric, literal, and anomalous sentences. Building upon previous research, we predicted that the relationship between the processing of creative meanings (i.e., novel metaphors) and language of operation would be modulated by mood, as indexed by N400 amplitude modulations (Pinheiro et al., 2013). Also, we exploratorily aimed to analyze potential mood-driven effects within the LPC window, given prior research exploring LPC modulations in response to positive and negative moods (Chwilla et al., 2011; Vissers et al., 2013; Naranowicz et al., 2022b). Namely, in the positive mood condition in L1, we expected L1 novel metaphors to evoke N400 and LPC responses of similar magnitudes as compared to L1 literal sentences, both eliciting attenuated ERP responses compared to anomalous sentences (Hypothesis 1). Such results would be consistent with facilitatory effects of mood on semantic processes observed in monolingual contexts (e.g., Federmeier et al., 2001; Pinheiro et al., 2013; Wang et al., 2016). In the negative mood condition, however, N400 and LPC responses elicited by L1 creative meanings should converge with those elicited by L1 anomalous sentences, both evoking more robust ERP responses compared to literal sentences (Hypothesis 2). Such a pattern would thus reflect increased processing difficulty, triggered by decreased attentional resources (e.g., Bolte et al., 2003; Forgas, 2018). In L2, in line with recent ERP research on novel meaning processing in bilinguals (Jankowiak et al., 2017; Jankowiak et al., 2021; Wang & Jankowiak, 2021), we expected the N400 and LPC amplitudes evoked by L2 novel metaphors to converge with those evoked by L2 anomalous sentences regardless of mood, reflecting reduced mood effects in L2 (Hypothesis 3; Naranowicz et al., 2022b). Such a prediction would simultaneously point to reduced emotional sensitivity in L2 (Wu & Thierry, 2012) and/or differential implicit emotional regulation mechanisms in L1 and L2 (Morawetz et al., 2017).

2. Methods

2.1. Participants

Fifty-one Polish–English bilinguals participated in the study, four of whom were excluded from the analyses due to low quality of the recorded EEG data (i.e., heavy Alpha contamination). The final sample therefore consisted of 47 participants aged 21–30 ($M_{Age} = 23.32$, 95 % CI [22.72, 23.92]), who were students or graduates of English Studies at the Faculty of English, Adam Mickiewicz University, Poznań. Participants were randomly assigned to either a native ($n = 24$) or a non-native ($n = 23$) language block (i.e., a between-subject design). Due to gender-driven mood effects on language processing observed in previous research (e.g., Naranowicz et al., 2022a), only females participated in the present study. Consistent with de Groot (2011), participants were classified as highly proficient unbalanced late Polish–English bilinguals who had not lived in the L2 (English) environment and had acquired their L2 in an instructional yet immersive learning context (see Table 1). All participants were in a generally good affective state, reporting low degrees of depression, anxiety, or stress around the time of data collection, as corroborated by DASS-21 (Lovibond & Lovibond, 1995; see Supplementary materials for the results of the DASS-21 questionnaire). They had normal/corrected-to-normal vision and hearing and no neurological, mood, psychiatric, and language disorders. Additionally, the Big Five Inventory (Goldberg, 1992), Empathy Quotient (Baron-Cohen & Wheelwright, 2004), and Interpersonal Reactivity Index (Davis, 1980) were used to assess participants' personality and empathy-related traits, which could potentially interact with their susceptibility to mood manipulation (see Supplementary materials for the results of the questionnaires). For their participation, participants received a gift card of 200 PLN and extra credit points.

2.2. Linguistic and mood-inducing stimuli

Linguistic stimuli. The linguistic stimuli included 180 Polish and 180 English sentences divided into three categories: 60 novel metaphors (e.g., *My heart is a* ***drawer*** *for secret feelings.; Bacteria are* ***fighters*** *attacking the immune system.; Motivation is an* ***engine*** *keeping our actions going.*), 60 literal sentences (e.g., *This piece of furniture is a* ***drawer*** *filled with socks.; These boxers are* ***fighters*** *from a local club.; This machine is an* ***engine*** *running on petrol.),* and 60 anomalous sentences (e.g., *A bug is a* ***drawer*** *shut with a bang.; Gifts are* ***fighters*** *warming up all together.; A frog is an* ***engine*** *repaired yesterday.*) in each language (see Supplementary materials for the whole list of stimuli). The linguistic stimuli were adopted from a database by Jankowiak (2020) that provides a set of pre-tested novel metaphors, literal, and anomalous sentences. The stimuli were highly controlled for their level of meaningfulness, familiarity, and metaphoricity by means of conducting 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; $M = 3.93$, $SD = 0.56$), number of letters ($M = 6.57$, $SD = 1.45$) and syllables ($M = 2.34$, $SD = 0.48$), as well as a cognate status (Jankowiak, 2020). Since the original database (Jankowiak, 2020) provides sentences where critical words are placed in a sentence-final position, we lengthened the original sentences so that the critical (ERP time-locking) words could be placed in a mid-sentence position, thus minimizing the likelihood of sentence wrap-up mechanisms that could affect critical word processing. Additionally, so as to avoid potential response strategies to literal as compared to non-literal sentences, we counterbalanced the novel metaphoric sentence meaningfulness such that, out of 60 novel metaphors in each language, half had a meaningful ending (e.g., *Ambition is a* ***mountain*** *conquered by students.*), and half – a meaningless ending (e.g., *Knowledge is* ***luggage*** *carried by book monkeys.*). Furthermore, we used Polish/English translation equivalents for each sentence, making the set fully counterbalanced. Crucially, at the point of critical word presentation, all novel metaphors and literal sentences were semantically meaningful, while all anomalous sentences were meaningless (Jankowiak, 2020).

All sentences were declarative and emotionally-neutral. All Polish sentences featured 5–10 words ($M_{NovelMetaphors} = 6.03$, $SD = 0.83$; $M_{LiteralSentences} = 6.92$, $SD = 0.90$; $M_{AnomalousSentences} = 5.99$, $SD = 0.94$). The critical words were presented in the 3rd/4th position in a sentence. Similarly, all English sentences were 5–12 words long ($M_{NovelMetaphors} = 7.82$, $SD = 1.36$; $M_{LiteralSentences} = 8.36$, $SD = 1.31$; $M_{AnomalousSentences} = 8.01$, $SD = 1.50$). The critical words were presented as the 3rd/4th/5th words. The larger number of words per sentence in English compared to Polish was due to articles in English, which do not exist in Polish.

Mood-inducing stimuli. We adapted 28 affectively evocative animated films of 90 s each from Naranowicz et al. (2022a) to elicit positive ($n = 14$) and negative moods ($n = 14$; see Supplementary materials). The films were highly controlled for mood valence and arousal in a series of norming tests (Naranowicz et al., 2022a), which showed that the films selected to induce a positive mood were rated as significantly more positive than those selected to induce a negative mood (p <.001), and there was no difference between the two film types in terms of their arousal (p =.071; see Naranowicz et al., 2022a for details). To sustain the evoked targeted mood, each selected film clip was additionally divided into two 45-second clips, which resulted in the presentation of 56 film fragments (i.e., 42 min in total) in both mood conditions.

2.3. Procedure

The procedure applied in the experiment was approved by the Ethics Committee for Research Involving Human Participants at Adam Mickiewicz University, Poznań. The experiment was carried out in the Neuroscience of Language Laboratory (Faculty of English, Adam Mickiewicz University, Poznań), located in the Center for Advanced Technology at Adam Mickiewicz University, Poznań. Participants were randomly assigned to one of the two language blocks: Polish (L1) or English (L2; a counterbalanced order), and the experiment was entirely conducted in either L1 or L2 (a between-subject design). Participants were seated in a dimly lit and quiet booth, 75 cm away from a LED monitor with a screen resolution of 1280 × 1024 pixels. E-prime 3.0 was used to present the stimuli and collect the behavioral data, and BrainVision Recorder 1.23 was used to collect the EEG data.

Participants were asked to rate their mood prior to and after mood manipulation and complete the Polish version of the PANAS (Watson et al. (1988) as translated into Polish by Fajkowska & Marszał-Wiśniewska (2009)). They first watched four mood-inducing film fragments and were instructed to put themselves in the targeted mood (Rottenberg et al., 2018), by imagining themselves as one of the protagonists and sympathizing with them (Werner-Seidler & Moulds, 2012). Then, participants were presented with a set of sentences and performed a semantic decision task, wherein they decided if a sentence was meaningless or meaningful by pressing designated keys, whose designation and order was counterbalanced. Each film clip was presented every ten sentences (in a counterbalanced order) to sustain the targeted mood. Participants completed one block with negative films and one block with positive films within each session (in a counterbalanced order), each comprising 60 novel metaphoric, 60 literal, 60 anomalous sentences, and 60 filler (meaningless) sentences ($n_{Total} = 480$ sentences). The sentences were randomly presented on a computer screen using black letters and were centered on a gray background. The time sequence of stimuli presentation is provided in Fig. 1.

Table 1
Participants' sociolinguistic data (means with 95 % CI).

	Polish (L1)	English (L2)
Proficiency[1]	n/a	86.41 [84.60, 88.23]
Proficiency[2]	97.72 [96.48, 98.96]	87.55 [85.83, 89.28]
Listening skills	6.98 [6.94, 7.00]	6.28 [6.12, 6.43]
Speaking skills	6.77 [6.63, 6.90]	5.91 [5.74, 6.09]
Reading skills	6.94 [6.87, 7.00]	6.38 [6.24, 6.52]
Writing skills	6.70 [6.51, 6.90]	5.91 [5.72, 6.11]
Dominance[2]	61.34 [59.14, 63.54]	53.62 [51.55, 55.68]
Immersion[2]	78.32 [75.16, 81.48]	69.29 [67.07, 71.52]
Age of acquisition[2]	n/a	6.51 [6.98, 7.04]

[1] LexTALE (Lemhöfer & Broersma, 2012; percentages);
[2] Language History Questionnaire 3.0 (Li et al., 2020, as translated into Polish by Naranowicz & Witczak): the proficiency, dominance, and immersion scores (percentages); listening, speaking, reading, and writing skills (1 – very low proficiency, 7 – very high proficiency); age of acquisition (years).

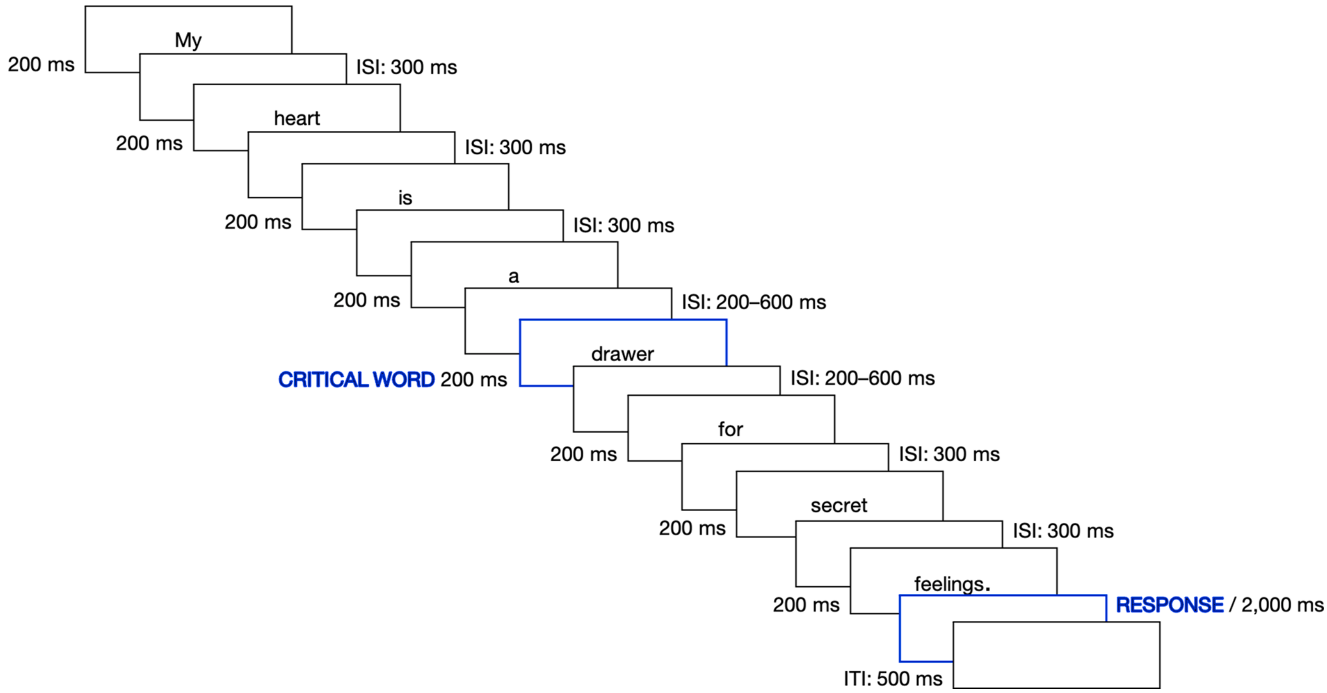

Fig. 1. Time sequence of stimuli presentation.

2.4. EEG data recording

EEG signals were recorded from 64 active actiCAP slim electrodes (Brain Products), placed at the standard extended 10–20 positions. The bipolar electrodes monitoring vertical (vEOG) and horizontal (hEOG) eye movements were placed above and below the left eye and next to the outer rims of both eyes, respectively. The EEG signals were amplified using a BrainVision actiCHamp amplifier (Brain Products), referenced to Fz, and sampled at 500 Hz. ERPs were time-locked to the onset of the critical word of each sentence, which was placed in a mid-sentence position.

2.5. Self-report and behavioral data analysis

All data analyses were performed in R (R Development Core Team, 2020). As part of self-report measures, participants rated their current mood with 7-point mood valence and arousal scales (i.e., bipolar dimensions) as well as PANAS (Watson et al., 1988), employing 10 positive adjectives (i.e., *positive affect*) and 10 negative adjectives (i.e., *negative affect;* i.e., unipolar dimensions). The summed positive and negative affect scores were presented as a ratio to make them comparable to mood valence ratings. Mood ratings were analyzed using repeated measures (RM) *ANOVAs* on the basis of a 2 (Time of testing: Pre-experiment vs Post-experiment) × 2 (Film type: Positive vs Negative) within-subject design, with Language (Polish [L1] vs English [L2]) as a between-subject factor. To ensure the effectiveness of our mood manipulation, we compared mood valence, arousal, and PANAS ratings post- relative to pre-experiment separately in each mood condition as planned comparisons, predicting increased/comparable mood ratings in the positive mood condition along with decreased mood ratings in the negative mood condition.

Behavioral data analyses were based on response accuracy (see Supplementary materials for accuracy rates results) data only, so as to measure participants' engagement in the task. Reaction times were, on the other hand, uninformative due to the fact that they were time-locked to the final word of a sentence, while the critical words were placed in a mid-sentence position. Also, participants were likely to have selected their response before the presentation of a final word of a sentence. However, it must be noted that behavioral data (both reaction times and accuracy rates) and ERP patterns measured in the present study did not primarily relate to one another, because ERPs were time-locked to critical words placed in a mid-sentence position and behavioral responses reflected the processing of the complete sentence in every case.

2.6. Electrophysiological data analysis

We analyzed two ERP components previously reported to be modulated by metaphoricity level (e.g., Jankowiak et al., 2017), language of operation (e.g., Jończyk et al., 2016), and mood (e.g., Naranowicz et al., 2022b): the N400 and LPC. In line with previous studies on bilingualism and semantic processing (Wu & Thierry, 2012; Jończyk et al., 2016; Naranowicz et al., 2022b), both components were analyzed over the FC1, FCz, FC2 (fronto-central), C1, Cz, *C*2 (central), CP1, CPz, and CP2 (centro-parietal) electrodes. The analyses were performed within pre-defined time windows, in accordance with previous electrophysiological research: 300–500 ms (N400; e.g., Kuperberg et al., 2003; Lau et al., 2016; Delogu et al., 2019) and 600–800 ms (LPC; e.g., Dowens et al., 2010; Jankowiak et al., 2021).

BrainVision Analyzer 2.1 software (Brain Products) was used to analyze the data offline. Continuous EEG data were re-referenced to the common average reference (Nunez & Srinivasan, 2006; Luck, 2014) and filtered offline (Butterworth zero phase filters) with a high-pass filter set at 0.1 Hz (slope 24 dB/octave) and a low-pass filter set at 20 Hz (slope 24 dB/octave). They were then segmented from 200 ms before critical word onset to 1500 ms afterward, baseline-corrected relative to signal between −200–0 ms before stimulus onset, and edited for artifacts (i.e., rejecting trials with flatlining events, voltage differences higher than 100 µV, or voltage steps higher than 50 µV). Ocular artifacts were corrected using the ocular artefact regression method by Gratton et al. (1983).

Within both the N400 and LPC time frames, mean ERP amplitudes were analyzed employing a 2 (Mood: Positive vs Negative) × 3 (Sentence type: Literal sentences vs Novel metaphors vs Anomalous sentences) within-subject design, with Language (Polish [L1] vs English [L2]) as a between-subject factor. The Greenhouse-Geisser correction was applied when the sphericity assumption was violated, as indicated by the Mauchly's tests.

3. Results

3.1. Self-report data: Mood ratings

For the mood valence and PANAS ratings, the RM *ANOVA* showed a Film type × Testing time interaction, $F_{MoodValence}(1, 45) = 27.68$, $p < .001$, $\eta_p^2 = 0.381$, $F_{PANAS}(1, 45) = 16.34$, $p < .001$, $\eta_p^2 = 0.266$, as well as main effects of both Film type, $F_{MoodValence}(1, 45) = 34.70$, $p < .001$, $\eta_p^2 = 0.435$, $F_{PANAS}(1, 45) = 22.74$, $p < .001$, $\eta_p^2 = 0.336$, and Testing time, $F_{MoodValence}(1, 45) = 84.87$, $p < .001$, $\eta_p^2 = 0.653$, $F_{PANAS}(1, 45) = 46.17$, $p < .001$, $\eta_p^2 = 0.506$ (see Fig. 2). As expected, planned comparisons showed decreased mood ratings in the negative mood condition ($p < .001$), with no change in valence ratings in the positive mood condition post- relative to pre-experiment ($p = .464$), regardless of language of operation. For the arousal ratings, the RM *ANOVA* showed only a main effect of Testing time, $F(1, 45) = 6.88$, $p = .012$, $\eta_p^2 = 0.133$ (see Fig. 2), whereby participants reported being more aroused after than before the experiment ($p < .001$), regardless of mood and language of operation. All remaining differences in mood ratings were non-significant, *ps* > 0.05.

3.2. Electrophysiological data: N400 (300–500 ms)

The RM *ANOVA* performed within the N400 time window (300–500 ms) yielded a main effect of Sentence type, $F(2, 90) = 9.39$, $p < .001$, $\varepsilon = 0.818$, $\eta_p^2 = 0.173$ (see Fig. 3), whereby literal sentences elicited reduced N400 amplitudes as compared to both novel metaphors ($p < .001$) and anomalous sentences ($p = .018$), with no difference between novel metaphors and anomalous sentences ($p = 1.00$). All remaining differences in N400 amplitudes were non-significant, *ps* > 0.05.

3.3. Electrophysiological data: LPC (600–800 ms)

Within the LPC time window (600–800 ms), a main effect of Sentence type was found, $F(2, 90) = 12.40$, $p < .001$, $\varepsilon = 0.874$, $\eta_p^2 = 0.216$, such that anomalous sentences elicited more pronounced LPC amplitudes relative to both novel metaphors ($p < .001$) and literal sentences ($p = .016$). There was no statistically significant difference between novel metaphors and literal sentences ($p = .291$; see Fig. 3).

Importantly, the analyses also revealed a Mood × Sentence type interaction, $F(2, 90) = 3.28$, $p = .043$, $\eta_p^2 = 0.068$ (see Fig. 4). *Post-hoc* analyses were conducted separately for each mood. In the positive mood condition, a main effect of Sentence type was found, $F(2, 90) = 15.35$, $p < .001$, $\eta_p^2 = 0.254$, whereby anomalous sentences elicited more pronounced LPC amplitudes relative to both novel metaphors ($p < .001$) and literal sentences ($p < .001$). There was no statistically significant difference between novel metaphors and literal sentences ($p = 1.00$). In the negative mood condition, on the other hand, no main effect of Sentence type was observed, $F(2, 90) = 2.31$, $p = .113$, $\varepsilon = 0.878$, $\eta_p^2 = 0.049$, with literal, novel metaphoric, and anomalous sentences all overlapping. All remaining differences in LPC amplitudes were non-significant, *ps* > 0.05.

4. Discussion

The present study explored how positive and negative moods regulate creative meaning processing, as exemplified by novel metaphors in L1 and L2. To this end, unbalanced Polish–English female bilinguals performed a semantic decision task to novel metaphoric, literal, and anomalous sentences in Polish (L1) and English (L2), after their mood was manipulated through exposure to animated films. We predicted creative meanings in L1 to be processed in a mood-dependent manner, with N400 and LPC responses to novel metaphors and literal sentences being reduced as compared to anomalous sentences in a positive mood (Hypothesis 1) and only literal sentences showing such reduction as compared to anomalous sentences in a negative mood (Hypothesis 2). In contrast, we expected the processing of creative meanings in L2 to be less mood-dependent, with the N400 and LPC responses to novel metaphor differing significantly from literal sentences but not from anomalous sentences in both positive and negative mood contexts. We found similar ERP patterns in L1 and L2 contexts, whereby in either of the two moods, novel metaphors patterned with anomalous sentences (i.e., differed from literal sentences) in the N400 time frame, and with literal sentences (i.e., differed from anomalous sentences) in the LPC time window. Interestingly, LPC responses were also differentially affected by mood: anomalous sentences evoked increased LPC amplitudes relative to both novel metaphoric and literal sentences in a positive mood, with no differences between the three sentence types in a negative mood.

First of all, within the N400 time window, we observed a main effect of sentence type, whereby novel metaphors converged with anomalous sentences, and both evoked a larger N400 response as compared to literal sentences. The fact that mechanisms engaged in novel metaphoric were more cognitively taxing than literal meaning processing is in line with previous electrophysiological results in the field (e.g., Arzouan et al., 2007; Lai et al., 2009), showing that highly creative and unfamiliar meaning processing requires extended lexicosemantic processes in conceptual mapping (Bowdle & Gentner, 2005).

A language-independent effect of sentence type was also found in the

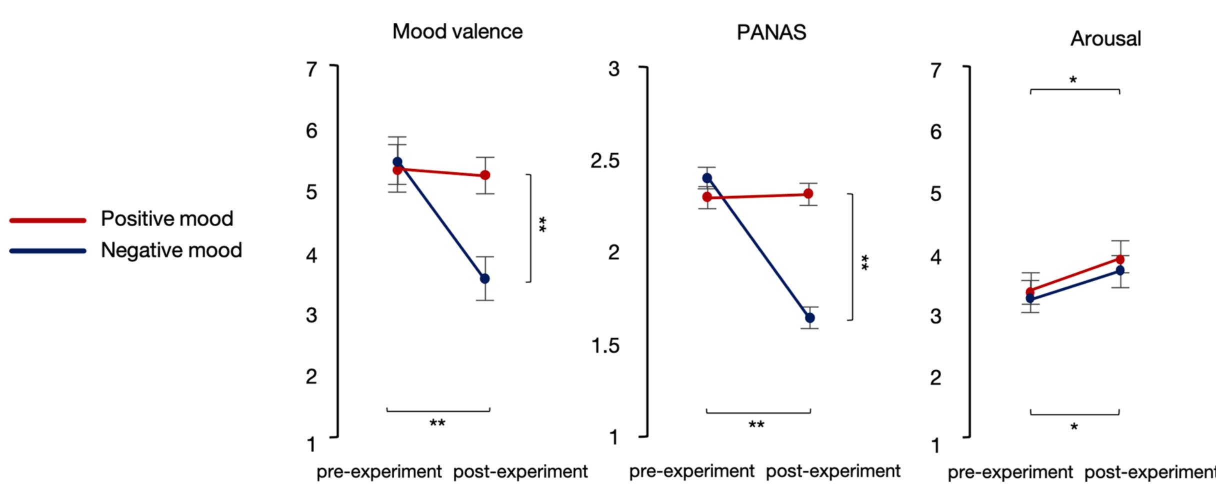

Fig. 2. Mood ratings for the mood valence scale (1 – *highly negative*, 7 – *highly positive*), the PANAS, the arousal scale (1 – *highly unaroused*, 7 – *highly aroused*) with CI of 95%.

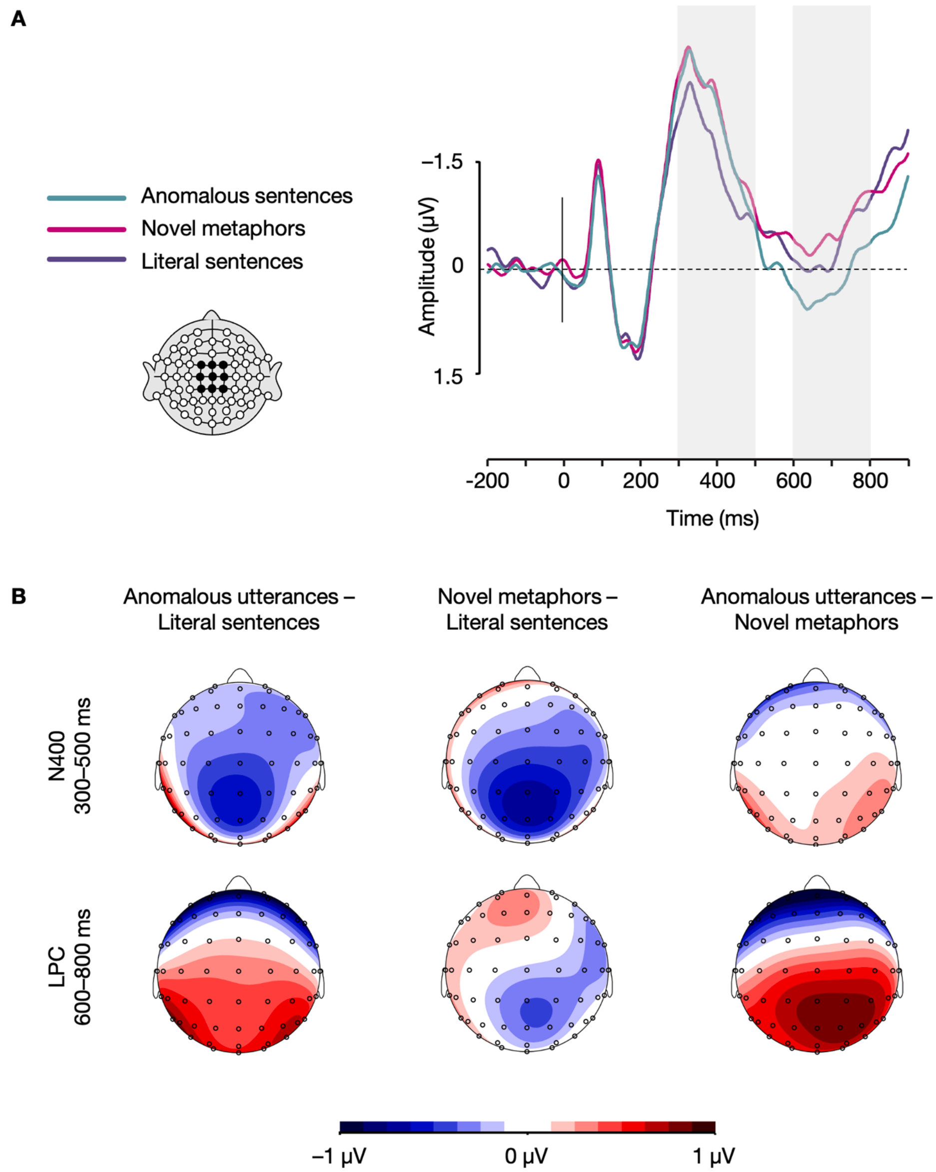

Fig. 3. Grand average ERPs for anomalous sentences, novel metaphors, and literal sentences in the 300–500 ms and 600–800 ms time windows **(A)**; topographic distribution of the differences between the mean amplitudes evoked by anomalous, novel metaphoric, and literal sentences in the 300–500 ms and the 600–800 ms time windows **(B)**.

LPC time range, where novel metaphors converged with literal sentences, both of which evoked smaller LPC amplitudes relative to anomalous sentences. A differential LPC response to anomalous relative to novel metaphoric sentences suggests that, though they were not initially processed differently from anomalous sentences, novel metaphors were still better integrated at the stage of meaning reevaluation (De Grauwe et al., 2010). Such findings are interesting in light of previous ERP research that has reported novel metaphors and anomalous utterances eliciting sustained negativity within the LPC window, pointing to a pervasive difficulty of novel metaphoric meaning integration (Goldstein et al., 2012; Tang et al., 2017a; Jankowiak et al., 2021). Such a sustained negativity, unlike the classic LPC effect, was mostly observed in studies in which ERPs were time-locked to the sentence final word (Tang et al., 2017a,b; Jankowiak et al., 2021). Therefore, such an effect might have been in part influenced by wrap-up effects, reflecting increased processing cost connected with final meaning integration (Just & Carpenter, 1980; Rayner et al., 2001; cf. Hirotani et al., 2006). Since a sentence wrap-up effect can be more pronounced when integrating semantically complex meanings (i.e., novel metaphors), in the present study, we decided to present critical words in a mid-sentence position, which may have made literal and novel metaphoric sentence integration more comparable. Anomalous sentences, however, evoked a robust LPC response possibly because of their systematic requirements for reanalysis (Kolk & Chwilla, 2007; Van de Meerendonk et al., 2009; Van de Meerendonk et al., 2010).

Interestingly, we also found an interaction between mood and sentence type within the LPC range. Namely, in a positive mood, a broadly distributed LPC sentence type effect was found, with significantly greater amplitudes for anomalous relative to both literal and novel metaphoric sentences, echoing the general trend found within the LPC time window described above. This observation is in line with Hypothesis 1, which predicted a facilitatory effect of a positive mood on creative meaning processing in L1. However, we failed to see any interaction with language of operation. Furthermore, partially consistent with Hypothesis 2, between-condition modulations observed in a positive mood vanished in a negative mood, where literal, novel metaphoric, and anomalous sentences all converged. These results accord with those observed by Vissers et al. (2013), who tested how film-

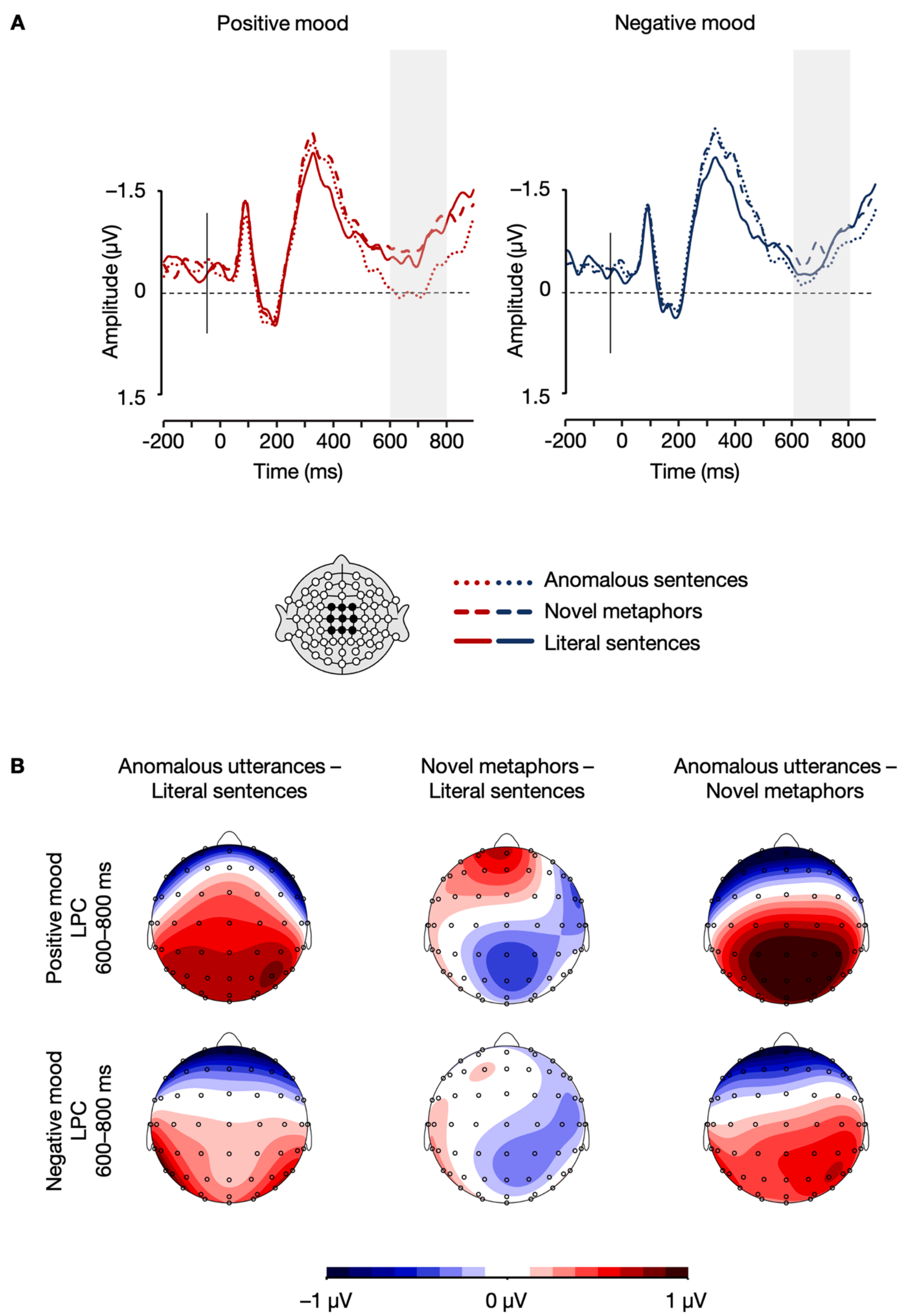

Fig. 4. Grand average ERPs for anomalous sentences, novel metaphors, and literal sentences in the positive and negative mood conditions in the 600–800 ms time window **(A)**; topographic distribution of the differences between the mean LPC amplitudes evoked by anomalous, novel metaphoric, and literal sentences in the positive and negative mood conditions in 600–800 ms time window **(B)**.

induced positive and negative moods affect semantically plausible and implausible sentences processing (i.e., compliant or conflicting with general world knowledge). While the authors did not observe N400 modulations by mood, implausible sentences elicited larger LPC amplitudes relative to plausible sentences in a positive mood but not in a negative mood. This suggests that at the stage of meaning integration, a positive mood activates top-down, heuristics-based, assimilative processing (i.e., relating incoming information to accessible stored information), while a negative mood inhibits the same process, promoting bottom-up, accommodative processing (i.e., focusing on perceptual stimuli from the environment, without associating them with stored knowledge; Schwarz & Clore, 1983; Chwilla et al., 2011; Vissers et al., 2013). Critically, both the paradigm used by Vissers et al. (2013) and the present study employed comparable linguistic and mood-inducing stimuli. First, similarly to Vissers et al. (2013), semantically anomalous and literal sentences were built here in line with general world knowledge expectations. Second, Vissers et al. (2013) also elicited positive and negative moods employing continuous mood induction with films (and presenting additional films in-between sentence presentation to sustain the target mood). In line with Vissers et al. (2013), the differential effects of positive and negative moods observed in the present study point to the activation of mood-dependent processing style during semantic information reanalysis on the basis of pre-existing general knowledge. Specifically, a negative mood might promote an enhanced attentive and detail-oriented thinking that may suppress the activation of heuristics (Ruder & Bless, 2003), resulting in a decreased re-evaluation of not only literal and metaphoric sentences but also anomalous sentences.

Yet, the effect of mood on semantic processing was reflected only within the LPC time frame, while some previous ERP studies have also reported mood-dependent modulations in the N400 time window (e.g., Chwilla et al., 2011; Pinheiro et al., 2013; Naranowicz et al., 2022b). Importantly, however, differential effects of positive and negative moods on semantic access, as indexed by the N400 modulations, were previously mostly observed in response to stimuli manipulated in terms of their expectancy (e.g., Chwilla et al., 2011; Pinheiro et al., 2013; Naranowicz et al., 2022b). In the present study, similarly to Vissers et al. (2013), we used sentences that were either plausible or implausible in relation to general world knowledge, as opposed to highly semantically constrained sentences, and we also failed to observe mood-driven N400 modulations. This indicates that whilst mood may modulate N400 effects driven by word expectancy manipulations, it may have less impact when plausibility is manipulated.

Contrary to one of our predictions, we found no evidence for a differential effect of language of operation on the interplay between mood and creative meaning processing, as reflected in the N400 and LPC patterns. This finding is not readily consistent with previous research on emotion–bilingualism interaction, which has suggested variations in implicit emotion regulation mechanisms and/or reduced emotional sensitivity in L2 compared to L1 (Wu & Thierry, 2012; Morawetz et al., 2017; Naranowicz et al., 2022b). Even though our results might be interpreted as partially consistent with those of the ERP study by Kissler and Bromberek-Dyzman (2021), who observed an interaction between mood and language of operation within the early N1 time range but not in the range of later semantics-related markers (i.e., N400 and LPC), their study employed affective words, and therefore, unlike the present experiment, tapped into affect-laden mechanisms engaged in single word processing. A more directly comparable result was obtained by Naranowicz et al. (2022b), who tested the influence of positive and negative moods on meaningful and meaningless sentence processing in unbalanced Polish–English bilinguals. Naranowicz et al. (2022b) observed a broadly distributed LPC sentence type effect (i.e., larger LPC amplitudes for meaningless relative to meaningful sentences) in both L1 and L2 in a positive mood, but increased LPC amplitudes for meaningful sentences in L2 relative to L1 only when participants were in a negative mood. Importantly, as in the present study, Naranowicz et al. (2022b) tested female bilingual speakers whose L2 proficiency was comparable to that of the participants tested here. Thus, differences in the results between the two studies cannot readily be accounted for by differences in L2 proficiency level or participant gender. The contrasting results between the current and previous studies may, therefore, stem from the particular stimuli employed, impacting cognitive mechanisms activated by positive and negative moods. As highlighted by Naranowicz et al. (2022b), the sentences featuring a semantic violation employed in their study were strongly unexpected but not entirely meaningless given that the contexts they were placed into could naturally evoke various semantic associations in participants tested (e.g., *These houses were transformed into country mansions/lobsters*…). Here, in contrast, we employed sentences with a transparent and repetitive syntactic structure (i.e., *A is B*), wherein semantic violations solely violated general world knowledge rather than a particular, elaborate semantic context. Thus, the effect of language of operation on mood–semantics interactions may be dependent upon the type of semantic context implemented. Namely, while a negative mood may activate different implicit emotion-regulation mechanisms and/or be associated with reduced emotionality during the processing of semantically rich information in L2 relative to L1 (Naranowicz et al., 2022b), it may affect L1 and L2 processing more similarly when meaning integration processes are based on general world knowledge. More research is however needed to fully understand how semantic context influences mood–language interactions in bilinguals.

5. Conclusion

The present study revealed ERP modulations by sentence type within two time windows of interest, showing that creative meaning differs from literal meaning integration at a lexico-semantic processing stage (indexed by the N400) and from meaningless sentences during a semantic re-evaluation stage (indexed by the LPC). The results also yielded an interaction between mood and sentence type within the LPC time frame that did not depend on language of operation: in a positive mood, anomalous sentences evoked a more pronounced LPC response relative to both literal and novel metaphoric sentences, whilst no difference was observed in a negative mood. A negative mood might therefore promote more attentive and detail-oriented processing, thus decreasing meaning re-evaluation based on pre-existing general knowledge of not only literal and novel metaphoric meaning but also anomalous content. The lack of an interaction between mood and language (L1 vs L2) in the current study might seem surprising, given that previous research has shown modulation of affective processing by language of operation. Yet, the effects observed here suggest that mood effects do not differentially affect L1 and L2 processing when meaning integration mechanisms depend on pre-existing world knowledge. Future research is needed to shed more light on the interplay between mood, different depths of semantic processing, and languages of operation.

Funding

This work was supported by Adam Mickiewicz University, Poznan, under the Excellence Initiative – Research University (Grant No 017/02/SNJL/0001).

Guillaume Thierry was supported by the Polish National Agency for Academic Exchange (NAWA) under the NAWA Chair Programme (PPN/PRO/2020/1/00006).

CRediT authorship contribution statement

Katarzyna Jankowiak: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. **Marcin Naranowicz:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Guillaume Thierry:** Conceptualization, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All the experimental stimuli, R scripts, and supplementary materials are available at: https://osf.io/uksm3/.

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Appendix O: Research article 4 (Naranowicz 2022)

Naranowicz, Marcin. 2022. “Mood effects on semantic processes: Behavioural and electrophysiological evidence”, *Frontiers in Psychology* 13: 1014706. doi: https://doi.org/10.3389/fpsyg.2022.1014706.

frontiers | Frontiers in Psychology

TYPE Review
PUBLISHED 11 November 2022
DOI 10.3389/fpsyg.2022.1014706

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to
Language Sciences,
a section of the journal
Frontiers in Psychology

RECEIVED 08 August 2022
ACCEPTED 24 October 2022
PUBLISHED 11 November 2022

CITATION
Naranowicz M (2022) Mood effects on semantic processes: Behavioural and electrophysiological evidence.
Front. Psychol. 13:1014706.
doi: 10.3389/fpsyg.2022.1014706

Mood effects on semantic processes: Behavioural and electrophysiological evidence

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Mood (i.e., our current background affective state) often unobtrusively yet pervasively affects how we think and behave. Typically, theoretical frameworks position it as an embodied source of information (i.e., a biomarker), activating thinking patterns that tune our attention, perception, motivation, and exploration tendencies in a context-dependent manner. Growing behavioural and electrophysiological research has been exploring the mood–language interactions, employing numerous semantics-oriented experimental paradigms (e.g., manipulating semantic associations, congruity, relatedness, etc.) along with mood elicitation techniques (e.g., affectively evocative film clips, music, pictures, etc.). Available behavioural and electrophysiological evidence has suggested that positive and negative moods differently regulate the dynamics of language comprehension, mostly due to the activation of mood-dependent cognitive strategies. Namely, a positive mood has been argued to activate global and heuristics-based processing and a negative mood – local and detail-oriented processing during language comprehension. Future research on mood–language interactions could benefit greatly from (i) a theoretical framework for mood effects on semantic memory, (ii) measuring mood changes multi-dimensionally, (iii) addressing discrepancies in empirical findings, (iv) a replication-oriented approach, and (v) research practices counteracting publication biases.

KEYWORDS

mood, semantic processes, mood induction procedures, processing styles, affective neurolinguistics, lexicosemantic access, N400, LPC

Introduction

We experience mood fluctuations of varying intensity, which often subconsciously cloud our judgement and colour our perception. To better understand the complexity of mood effects on cognitive processes, mood changes have been explored in the last three decades mainly from behavioural and electrophysiological perspectives. Overall, most mood research has revolved around two broad categories of a positive and negative mood, consistently pointing to differential cognitive consequences of these two opposite affective states (see Forgas, 2017 for a review). In consequence, various theoretical frameworks have been offered, accounting for and predicting how mood tunes our mental processes.

Concurrently, mood researchers have been refining various mood induction procedures (MIPs) – the experimental techniques for ecologically valid and ethically minded mood elicitation under laboratory conditions that reflect mood fluctuations experienced on a daily basis (see Westermann et al., 1996; Lench et al., 2011; Fakhr Hosseini and Jeon, 2017 for reviews).

Growing scholarly attention has been devoted to a potentially reciprocal relationship between mood and language. The mood–language interactions have been explored in various linguistic domains, including syntactic processing (Vissers et al., 2010; Jiménez-Ortega et al., 2012; Van Berkum et al., 2013; Verhees et al., 2015; Liu et al., 2018; Yano et al., 2018), language production (Isen et al., 1985; Beukeboom and Semin, 2006; Kharkhurin and Altarriba, 2016; Hinojosa et al., 2017; Braun et al., 2019; Forgas and Matovic, 2020; Out et al., 2020), communicative interactions (Forgas, 1999; Koch et al., 2013; Matovic and Forgas, 2018), reading patterns (Bohn-Gettler and Rapp, 2011; Scrimin and Mason, 2015; Mills et al., 2019), and emotional word processing (e.g., Kiefer et al., 2007; Pratt and Kelly, 2008; Egidi and Nusbaum, 2012; Kissler and Bromberek-Dyzman, 2021; Naranowicz et al., 2022a). Arguably, semantic processing (i.e., the cognitive mechanisms engaged in language comprehension) has attracted a particularly keen interest among mood researchers, who have employed a variety of behavioural (e.g., Storbeck and Clore, 2008; Sakaki et al., 2011; Matovic et al., 2014) and electrophysiological measures (e.g., Goertz et al., 2017; Ogawa and Nittono, 2019a,b; Naranowicz et al., 2022b) to understand the principles guiding the relationship between our current affective state and how we understand language.

Defining affective constructs

Mood as an affective construct is typically defined through a comparison with *emotion*. Overall, mood and emotion are two affective phenomena differing in duration and intensity, with emotion being characterised as short-lived and rather intense and mood as enduring and mild affective states (Ekman, 1992). Unlike event-triggered full-blown emotion, mood can also be characterised as a diffuse and pervasive background affective state that is rarely associated with a particular object or person (e.g., Elman, 1994; Frijda, 2009). A discrete mood state (e.g., frustration, anxiety, stress, etc.) may still be triggered by an antecedent cause or mood-congruent emotional responses, though (e.g., Morris, 1992; Ekkekakis, 2013). Moreover, the two affective constructs are the products of different appraisal-driven mechanisms: emotions originate from the appraisal of a narrow "adaptational encounter with the environment," and moods stem from the appraisal of broad "existential issues of one's life" (Lazarus, 1991: 48). Consequently, whereas the primary function of emotion is to equip us with action packages guiding our immediate behavioural, physiological, and neurological responses in an adaptive fashion (see Nielsen and Kaszniak, 2007 for a review), mood generally tunes our cognitive mechanisms to adapt thinking patterns to our subjective experiences (Schwarz and Clore, 1983). Compared to emotion, mood can also be more strongly affected by interoception (i.e., sensory input from physiological responses or peripheral organs), as reflected by mood fluctuations due to hormones, inflammation, sickness, etc. (Pace-Schott et al., 2019).

Building upon the mood–emotion distinction outlined above, in the present review, I refer to mood as a slowly changing, low-intensity background affective state that mostly unobtrusively fluctuates over time from feeling positive (i.e., pleasant/good) to negative (i.e., unpleasant/bad), with its primary adaptational function being to tune our thinking patterns in a context-dependent manner (see also Forgas, 2017).

Scope of the present review

The primary aim of this paper is to review accumulating behavioural and electrophysiological research showing how positive and negative moods (i.e., opposite background affective states) modulate the cognitive mechanisms engaged in language comprehension. After outlining the key theoretical frameworks relevant for mood effects on cognitive processing, I focus on ethically-minded methodological aspects of experimental mood elicitation. Next, I review behavioural and electrophysiological research on mood–semantics interactions, considering a range of language comprehension-oriented experimental paradigms. Finally, the paper offers a critical overview of the theoretical and empirical underpinnings of mood–semantic processing interactions, highlighting potential future research directions.

Theoretical considerations

Selected theoretical approaches to mood and cognitive processes

Early theoretical frameworks have emphasised highly adaptive motivational consequences of positive and negative moods. First, Clark and Isen (1982) put forward the *affect maintenance* hypothesis, whereby being in a positive mood can subconsciously motivate maintaining such a favourable state of mind by refraining from any effortful, elaborate thinking. In contrast, engagement in vigilant and effortful processing in a negative mood can serve as an adaptive strategy, aiming to improve one's mood. Then, Schwarz (1990, 2002) developed the *cognitive tuning* hypothesis, suggesting that one's cognitive processes are regulated by mood to satisfy situational requirements. A negative mood, signalled by negative environmental cues or bodily avoidance feedback (i.e., bodily sensations linked to negative outcomes), is believed to warn us against a problematic situation, motivating a vigilant and effortful processing style. Conversely, a positive mood, signalled by positive environmental cues or bodily approach feedback (i.e., bodily sensations linked to positive outcomes), is assumed to invite reliance on tried and trusted routines, promoting an effortless processing style.

Schwarz and Clore (1983; see also Clore et al., 2001; Clore and Storbeck, 2006) offered a detailed theoretical view on how mood can affect evaluative judgements – the *affect-as-information* (AAI) hypothesis. The AAI hypothesis postulates that affective states (i.e., emotions and moods) are experiential and embodied sources of information about the personal value of whatever is being processed. Emotions and moods reflect unconscious appraisals, typically represented on two orthogonal dimensions of valence (i.e., pleasantness) and arousal (i.e., importance and urgency). The AAI hypothesis assumes misattribution of one's current mood (i.e., an inferential error) as a response to an object of judgement, leading to its more and less favourable evaluation in a positive and negative mood, respectively. Consequently, positive and negative moods are believed to activate contrastive context-dependent processing styles in problem-solving situations: while a positive mood reinforces top-down relational processing (i.e., relating incoming information to accessible stored information, including knowledge, beliefs, expectations, and stereotypes), a negative mood impedes it, promoting bottom-up referential processing (i.e., focusing on perceptual stimuli from the environment, without associating them with the stored knowledge). In line with the AAI hypothesis, mood is also conceptualised as a marker of task-dependent processing requirements: a positive mood is associated with cognitive ease, motivating effortless and heuristics-based processing, whereas a negative mood signals cognitive difficulty, instigating effortful and systematic processing. The AAI hypothesis also suggests that mood governs available attentional resources: positive and negative moods lead to a global (i.e., top-down) or a local (i.e., bottom-up and detail-oriented) focus of attention, respectively.

Forgas (1995, 2002) proposed an integrative theoretical approach – the *Affect Infusion Model* (AIM) – to account for the control of information processing strategies by mood. The AIM assumes that the intensity of *affective infusion* (i.e., a tendency for thoughts, memories, judgements, and behaviours to be mood-congruent) grows proportionately to context-specific cognitive demands and open information search, giving rise to four distinct processing strategies. First, the *direct access* strategy entails low-effort and automatic retrieval of already stored response that does not require rumination (e.g., retrieving one's phone number), and it is least impacted by one's mood. Second, the *motivated processing* strategy involves more effortful yet highly targeted thinking, dictated by a specific motivational objective (e.g., preparing for an exam), and it is minimally affected by one's mood. Third, the *heuristic processing* strategy concerns effortless subconscious evaluative processing, manifesting itself when such resources as time, interest, attention, motivation, and working memory capacity are in short supply (e.g., choosing an outfit for a party at the last minute). Consistent with AAI hypothesis (Schwarz and Clore, 1983), in such circumstances, one's affective state can be treated as a heuristic cue, leading to mood-congruent choices. Lastly, the *substantive processing* strategy assumes open and elaborate thinking triggered by a novel and cognitively demanding task in the absence of ready-made solutions (e.g., accidently having to change a career path), leading to the strongest mood-congruent effects.

Building on the AAI hypothesis (Schwarz and Clore, 1983), Bless (2001) proposed the *mood-and-general-knowledge* (MaGK) hypothesis, assuming that mood effects on cognition are associated with one's reliance on general knowledge structures. The MaGK hypothesis holds that experiencing a positive mood signals being in a benign situation, which consequently promotes reliance on pre-existing general knowledge structures and a heuristics-based, top-down thinking style. Conversely, experiencing a negative mood may be associated with eminent threat, motivating a more analytical, detail-oriented, bottom-up thinking style. The MaGK hypothesis also assumes that reliance on general knowledge structure in a positive mood saves up cognitive resources that can be allotted to other cognitive tasks and leads to making inferences beyond the information given (e.g., to form false memories).

Bless and Fiedler (2006) offered the *adaptive function* account – another theoretical perspective on how mood influences information processing styles. This account stipulates that, when attention drives thinking, mood effects on thinking styles are dictated by two complementary biological tendencies: *assimilation* (i.e., modifying new information to fit into internal structures) and *accommodation* (i.e., modifying internal structures to fit into new information). In line with the adaptive function perspective, a positive mood promotes an assimilative (i.e., schema-based and top-down) thinking style and a negative mood an accommodative (i.e., externally focused and bottom-up) thinking style.

Zadra and Clore (2011) put forward an alternative *bio-energetic* perspective on how mood alters cognitive processes. They proposed that mood serves as a biological marker of the number of resources that can be readily invested in exploratory (i.e., cognitively intense) behaviour. Specifically, affective states are assumed to involuntarily provide embodied information about energy costs and likely benefits of potential actions, acting in the interest of resource maintenance. Exploratory and exploitatory behaviours are therefore promoted by a positive and negative mood, respectively. Consistently with the AAI hypothesis (Schwarz and Clore, 1983), the bio-energetic perspective also capitalises on the attention-mediated global–local attentional focus, with a positive mood broadening the scope of attention (i.e., a global perceptual style) and a negative mood narrowing it (i.e., a local perceptual style). Moreover, the bio-energetic perspective highlights the role of arousal, whose main function is to direct available processing resources to the most significant (i.e., the most arousing) information.

Herz et al. (2020; see also Bar, 2021) developed the *State of Mind* (SoM) framework, offering a more holistic approach to one's psychological state of mind, emphasising the role of mood in its regulation. The SoM framework capitalises on an overarching and dynamic construct termed *state of mind* (i.e., one's current behavioural, cognitive, and affective inclinations) regulated by five inter-related dimensions of perception (sensory information vs. predictions), attention (global vs. local), thought (broad vs. narrow thinking style), openness to experience (exploration vs. exploitation), and affect (a positive vs. negative mood). All of the dimensions are assumed to change together in a synchronised manner, and their role is dictated by a varying ratio of bottom-up (i.e., a broad SoM) to top-down (i.e., a narrow SoM) cortical processing. Consistent with the SoM framework, being in a positive mood entails more bottom-up processing, accompanied by greater reliance on sensory information, a global focus of attention, a broad thinking style, and exploratory disposition. In contrast, being in a negative mood involves more top-down processing and, consequently, greater reliance on predictions, a local focus of attention, a narrow thinking style, and exploitatory disposition. Strikingly, while the “bottom-up” and “top-down” types of processing have consistently been associated with negative and positive mood, respectively, by other theoretical frameworks (e.g., Schwarz and Clore, 1983), Herz et al. (2020) propose the opposite mapping between processing styles and positive and negative moods.

Selected theoretical approaches to mood and language comprehension

Mood has also been incorporated into a recent theoretical model of language comprehension. Operating at the intersection of pragmatics, psycholinguistics, and affective research, van Berkum et al. (2018; see also Van Berkum, 2019) proposed the *Affective Language Comprehension* (ALC) model, emphasising the role of affect in language comprehension during communicative interactions. The first stage of the comprehension process entails activating and retrieving lexical, semantic, phonological, and syntactic representations of individual items from long-term memory, which are later pieced together and comprehended as a whole. The verbal message is communicated alongside non-verbal cues (e.g., gestures, gaze, facial expressions, etc.). The second stage of the process involves inferring (i.e., interpreting) the conventionalised meaning communicated by the speaker: their referential intention (i.e., to whom a given message refers), their stance (i.e., certainty as well as conscious or unconscious affective/evaluative orientation), their social intention (i.e., whether they intend to share, request, or inform about something), and bonus meaning (i.e., what can be inferred beyond the communicated meaning). The ALC model stresses the importance of *emotionally competent stimuli* (i.e., stimuli automatically triggering emotions), which can affect *all* individual processes involved in language comprehension, also accounting for such affective qualities as empathy, emotional contagion, empathetic concern, and affective perspective-taking. Crucially, the ALC model acknowledges that mood tunes cognitive processes, recognising the mediating role of the recipient’s mood in interpreting the conveyed message, and that emotionally evocative language itself may elicit a given mood. Yet, no mood-dependent cognitive consequences for language comprehension are stipulated by the model.

Methodological considerations

Mood induction procedures

Various MIPs have been employed by psycholinguists to experimentally manipulate participants’ mood. Typically, participants are exposed to well-controlled affectively evocative stimuli (e.g., film clips, music, pictures, written stories, self-referential statements, etc.) under laboratory conditions so as to temporarily alter and/or intensify their current affective states. Most experimental studies involving mood elicitation concentrate on two broad categories of positive and negative moods, assumed to reflect the mood fluctuations experienced in everyday life (see Westermann et al., 1996; Lench et al., 2011; Fakhr Hosseini and Jeon, 2017; Joseph et al., 2020 for reviews). In practice, a medium- or high-intensity pleasant or unpleasant affective state is elicited through repeated and rather intense exposure to stimuli charged with either positive or negative emotions, effects of which are expected to cumulate and affect the cognitive processes of interest throughout the entire experiment. Some mood researchers also incorporate a more elusive category of a “neutral” mood into their research designs: a baseline condition representing a low-intensity calming affective state, elicited through presentation of equivalent yet affectively neutral stimuli (e.g., a nature documentary instead of an affectively rich film fragment) or no manipulation (see Fernández-Aguilar et al., 2019 for a review).

Substantial evidence has pointed to greater emotional reactivity to negative compared to positive mood induction. In their systematic review, Joseph et al. (2020) estimated that on average negative content exerts nearly two times stronger mood changes than positive content, as indexed by self-reports. This finding is consistent with the negativity bias hypothesis (see Norris, 2021 for a review), whereby negative relative to positive events generally have greater impact on our cognitive state (e.g., behaviour, perception, decision making, physiology, attention, etc.) due to different adaptive functions of positive and negative affective states. Namely, negative affective states signal the presence of a stimulus threatening one’s homeostatic balance, thereby eliciting survival-driven physiological and cognitive responses, which is not the case for positive affective states (Baumeister et al., 2001). It is also noteworthy that since participants typically are in a mildly positive mood upon arrival to the laboratory (Joseph et al., 2020), lack of a significant increase in mood ratings in the positive mood condition is not perceived as ineffective mood manipulation when participants maintain the targeted positive mood (e.g., Van Berkum et al., 2013).

Elicitation of positive and negative moods *via* film clips deserves special attention due to its highest potency among MIPs (Westermann et al., 1996; Joseph et al., 2020) and its prevalence in psycholinguistic research (e.g., Hänze and Hesse, 1993; Bless et al., 1996; Chwilla et al., 2011; Van Berkum et al., 2013; Vissers et al., 2013; Matovic et al., 2014; Goertz et al., 2017; Naranowicz et al., 2022a,b). Such affectively charged audio-visual materials have been favoured due to their ability to create affectively dynamic contexts that reflect real-life situations (i.e., they have high ecological validity; Fernández Megías et al., 2011), motivating high attentional engagement (Rottenberg et al., 2007), and eliciting the affective states lasting for exploitable lengths of time (Carvalho et al., 2012). From a practical perspective, a number of databases offering standardised and validated mood-inducing film clips have been developed (see Maffei and Angrilli, 2019), targeting both general (i.e., positive and negative moods) and discrete affective states (e.g., sadness, joy, fear, disgust, etc.). Though there is no clear consensus over the most desirable characteristics of mood-inducing film clips (e.g., genre, duration, brightness, etc.), Maffei and Angrilli (2019) estimated that 2 min is the optimal duration for film clips in terms of the effectiveness in inducing targeted moods and participants' engagement.

To intensify the mood effects elicited with film clips, some researchers have recommended (i) explicitly informing participants about the purpose of mood induction (Westermann et al., 1996), (ii) instructing participants to put themselves in the targeted mood (Rottenberg et al., 2018), (iii) asking participants to imagine themselves as one of the protagonists, and (iv) sympathising with other characters (Werner-Seidler and Moulds, 2012). A similar conclusion could also be drawn from a recent meta-analysis by Joseph et al. (2020), who revealed that affectively evocative films indeed exert the strongest effects on participants' affective states among all MIPs when the intent of mood induction is truthfully revealed to them. It remains an open question, however, if being fully aware of the fact that the affective context is created experimentally increases participants' emotional reactivity or promotes following demand characteristics (see the *Measuring mood changes* section below for more details).

Ethical considerations

In real life, deliberate manipulation of one's affective state has many facets and is generally considered immoral, especially when it involves deceptive and underhanded tactics. While triggering increased affective reactions remains a part and parcel of experimental mood research and is not readily perceived as manipulative, it remains critical to predict and minimise its potential negative consequences (Fakhr Hosseini and Jeon, 2017). Occurrences of mood disorders (e.g., clinical depression, bipolar disorder, borderline personality disorder, etc.) and recent traumatic events (e.g., a close relative's death) in prospective participants are the two ethical challenges particularly problematic in the case of negative mood induction. Exposure to such destressing content can seriously destabilise emotional well-being of vulnerable individuals. For instance, individuals with depression exposed to negative content are likely to excessively ruminate on their own symptoms, which typically exacerbates a negative mood and predicts depressive episodes (Joormann and Stanton, 2016). Potential participants should therefore be explicitly informed about the deeply emotional character of the mood-inducing stimuli beforehand, with particular attention devoted to increased risks to vulnerable individuals. Pre-screening procedures could also include a standardised psychometric test for common mood disorders (e.g., DASS-21 measuring one's level of depression; Lovibond and Lovibond, 1995), which can help identify individuals with undiagnosed mood disorders as well as those reluctant to openly report suffering from them in a medical history questionnaire. Moreover, to facilitate emotional recovery post negative mood induction, participants should be exposed to mood "reset" induction (e.g., evoking good memories from the past while listening to positive music; Joseph et al., 2020).

Measuring mood changes

Traditionally, experimentally evoked mood changes have been measured with self-report inventories, administered prior to, in-between, and post mood induction phases (see Gray and Watson, 2007; Ekkekakis, 2013 for reviews). Mood self-assessment is a metacognitive and introspective undertaking: participants are expected to identify and interpret elusive physiological sensations, take into account the surrounding context, and quantify all of these factors using rating scales (Gray and Watson, 2007).

The choice of a mood measure most informative in a given study could depend on whether one conceptualises mood as positioned along orthogonal dimensions or as a blend of distinct affective states, which aligns with conventional theoretical approaches to affective constructs (see Ekkekakis, 2013 for a review). First, participants are frequently asked to measure their current mood on two bipolar scales of mood valence (i.e., positive−−negative) and arousal (i.e., low−−high; e.g., Sakaki et al., 2011; Vissers et al., 2013; Wang et al., 2016). This is consistent with the *dimensional approach* to affect (e.g., Russell, 1980), positing that affective states can be represented along two orthogonal (i.e., unrelated) and bipolar dimensions of valence/pleasantness (i.e., an evaluative/hedonic component) and arousal/activation (i.e., an intensity component), the combination of which captures affective states. An alternative to two bipolar scales is the use of two separate unipolar scales of a positive mood (or happiness) and a negative mood (or sadness; e.g., Hesse and Spies, 1996; Bolte et al., 2003). While it is theoretically possible, such an approach does not assume that one concurrently experiences the two affective states at intense levels. In fact, positive and negative mood (or happiness and sadness) ratings post mood induction are usually negatively correlated: an increase in a positive mood/happiness is accompanied by a decrease in a negative mood/sadness, and vice versa (e.g., Scollon et al., 2005; Brehm and Miron, 2006; Joseph et al., 2020). Overall, the dimensional approach could be particularly informative in research taking a more holistic perspective on mood, that is, focusing on general positive and negative mood states.

Second, participants can also be asked to assess their current affective state by rating it on numerous unipolar scales, represented by mood-related state adjectives (e.g., Pinheiro et al., 2013; Van Berkum et al., 2013). Pinheiro et al. (2013), for instance, administered the Profile of Mood States questionnaire (PoMS; McNair et al., 1971): participants rated their current affective state using 65 state adjectives (e.g., *friendly, tense, angry,* etc.) or simple statements (e.g., *sorry for things done*, *ready to fight*, etc.). The ratings were then grouped into seven subcategories indexing different mood states (i.e., *depression, tension, anger, vigour, fatigue, confusion,* and *friendliness*). This is consistent with the *distinct-state approach* (also known as a *categorical approach* or *state-affect approach*) to affective constructs (e.g., Izard, 1993), positing that our current mood is a composite of unique and unrelated affective states that are believed to solve unique adaptive problems. The distinct-state approach seems to be most suitable for research on individual mood states (e.g., anxiety or tension); however, it has still been adopted in research on general positive and negative moods (e.g., Pinheiro et al., 2013; Van Berkum et al., 2013) to tap into a more detailed picture of experimentally induced mood states.

Despite being widely embraced by mood researchers, self-report mood questionnaires can be subject to a number of random and systematic measurement errors (see Gray and Watson, 2007 for a review). One of the potential threats to reliable mood assessment under laboratory conditions relates to the social desirability bias: a respondent's tendency to inaccurately answer socially sensitive questions, such as those related to their affective state, so as to be perceived in a more favourable light by others (Ekkekakis, 2013). Self-report mood measurements are also subject to demand characteristics: a respondent's tendency to behave in a manner they believe is expected of them (Fakhr Hosseini and Jeon, 2017). For instance, having watched a number of sad film clips or been informed about the purpose of mood induction (see the *Mood induction procedures* section above), participants may assume that they are expected to report a deterioration in their mood state, purposefully downgrading their mood ratings. Another potential problem lies in some people's inherent inability to identify or interpret physiological indicators of their affective states on top of countless other external factors influencing it, thereby leading to much variability in mood ratings. Nielsen and Kaszniak (2007) proposed that those participants who are more emotionally aware are better emotion regulators, and those who underwent an emotion-related formal training may be more aware of their affective experiences than others. Gray and Watson (2007), in turn, observed that, unlike "high awareness" participants, those insensitive to changes in their affective state may rely on cultural and gender stereotypes when rating their current mood (e.g., see the *Blue Monday* and *Thank God it's Friday* effects; Stone et al., 2012).

Mood effects on semantic processes

Behavioural evidence

Growing behavioural evidence has indicated that positive and negative moods may exert marked effects on semantic processes (e.g., Hänze and Hesse, 1993; Bless et al., 1996; Hesse and Spies, 1996; Bolte et al., 2003; Rowe et al., 2006; Storbeck and Clore, 2008; Sakaki et al., 2011; Matovic et al., 2014; see also Supplementary materials). Much behavioural research has concentrated on how mood affects spreading activation in semantic memory employing a semantic priming paradigm, wherein participants are presented with semantically (un)related prime–target word pairs (Hänze and Hesse, 1993; Hesse and Spies, 1996; Storbeck and Clore, 2008). In such a paradigm, researchers typically observe a so-called *semantic priming effect*: reduced response latencies for a target word (e.g., *dog*) preceded by a semantically related (e.g., *cat*) compared to an unrelated prime word (e.g., *car*), which is believed to reflect facilitated spreading activation of semantically related concepts (Hänze and Hesse, 1993). Semantic priming has been employed in combination with a lexical decision task (LDT; i.e., classifying a string of letters as a word or a non-word; Hänze and Hesse, 1993; Hesse and Spies, 1996; Storbeck and Clore, 2008) and a semantic categorisation task (SCT; i.e., judging semantic relatedness of presented category–member pairs; Storbeck and Clore, 2008; *cf.* Sakaki et al., 2011). Moreover, the organisation of semantic memory has also been explored through a remote association paradigm, wherein participants are typically presented with three words (i.e., word triads) somewhat semantically (dis)associated with a common fourth word and make intuitive judgements about their semantic coherence (Bolte et al., 2003; Rowe et al., 2006). Moreover, a remote association paradigm combined with perceptual tasks have also been used to test how mood influences attentional focus. Finally, some attention has also been devoted to the question of how mood affects reliance on general knowledge structures (i.e., heuristics), explored through the manipulation of information typicality and relevance (Bless et al., 1996).

As for a positive mood, behavioural research employing a semantic priming paradigm has suggested that it may facilitate spreading activation to close but not remote associates (i.e., the words of high/low semantic associations, respectively) in semantic memory (Hänze and Hesse, 1993). In an LDT, Hänze and Hesse (1993) explored how film-induced positive and neutral moods modulate semantic priming, manipulating the associative strength (high vs. low) of the prime–target pairs. They observed stronger semantic priming for the prime–target pairs of high but not low associative strength in a positive mood only, pointing to positive mood-driven improved spreading activation to closely associated concepts. Hänze and Hesse (1993) also concluded that such a facilitatory effect of a positive mood on the activation level may decrease proportionally to decreasing activation strength between two neighbouring concepts.

Still, facilitated activation spread to remote associates in semantic memory in a positive mood has actually been found in behavioural research employing a remote association paradigm (Bolte et al., 2003). Bolte et al. (2003) investigated how positive, negative, and neutral moods elicited by autobiographical recall alter intuitive semantic coherence judgements (i.e., their accuracy, duration, and confidence in the decisions made) about word triads weakly associated with a fourth word. They observed that the intuitive coherence judgements were more accurate in a positive relative to neutral and negative mood, with a negative mood leading to coherence judgements only at chance level. Bolte et al. (2003) proposed that a positive mood may promote and a negative mood may restrict the activation of widespread associative networks in semantic memory, linking such patterns with adapting mood-dependent cognitive strategies.

Further behavioural research employing a remote association paradigm has also indicated that a positive mood may result in increased breadth of attentional selection, facilitating cognitive processes that require a global attentional focus (e.g., semantic processing), at the same time impairing those that require a narrow attentional focus (e.g., perceptual processing; Rowe et al., 2006). In a series of semantic and perceptual experiments, Rowe et al. (2006) tested how music-induced positive, negative, and neutral moods affect intuitive coherence judgements in a remote association paradigm as well as visual selective attention, using strings of compatible letters or with one incompatible letter. They found that a positive compared to negative and neutral mood provoked increased generation of semantically distant associations, indicating a broader attentional focus triggered by a positive mood. They also observed slower RTs to incompatibility trials in a positive compared to negative and neutral moods, pointing to a potential adverse effect of a positive mood on selective attention.

Moreover, behavioural research has also suggested that a positive mood, associated with increased cognitive ease, may promote reliance on general knowledge structures (i.e., heuristics) to a greater extent than neutral and negative moods (Bless et al., 1996). In three semantic and perceptual experiments, Bless et al. (1996) investigated how positive, negative, and neutral moods (elicited through autobiographical recall and films) alter the recognition speed and accuracy of critical words (un)related to auditorily-presented stories, varying in information typicality and relevance. They found a stronger tendency among participants to erroneously classify typical in contrast to atypical and irrelevant information as related to a given story (i.e., an intrusion error) in a positive compared to negative mood, with a neutral mood falling in-between. Bless et al. (1996) suggested that such reliance on pre-existing knowledge in a positive mood could not result from decreased processing capacities or motivation, as a positive compared to neutral and negative mood also facilitated response accuracies in a secondary concentration task (i.e., identification of certain physical attributes of letters).

Regarding a negative mood, previous behavioural research employing semantic priming has pointed to its inhibitory effects, translated into dampened activation of semantic associations in semantic memory (Storbeck and Clore, 2008). Note that such a finding has also been corroborated by research employing a remote association paradigm (Bolte et al., 2003). Storbeck and Clore (2008) studied how music-induced positive, negative, and neutral moods influence semantic priming in an LDT and an SCT as well as affective priming (i.e., faster RTs to a target word affectively congruent relative to incongruent with a prime) in an evaluative task (i.e., classifying words as positive or negative). To this aim, they used the prime–target pairs varying in word status (i.e., words vs. non-word), semantic categories (i.e., animal- vs. texture-related), and word valence (i.e., positive vs. negative), respectively. They observed semantic and affective priming effects in positive and neutral moods, with no such effects in a negative mood, suggesting that a negative mood may actually result in impaired spreading activation in semantic memory. Also, Storbeck and Clore (2008) suggested that such results do not contradict the previously observed facilitatory effect of a positive relative to neutral mood on semantic priming, given that their participants in the neutral (i.e., baseline) mood condition had in fact reported being in a mildly positive mood.

Further behavioural research has offered corroborative evidence for deleterious effects of a negative mood on spreading activation in semantic memory (Bolte et al., 2003; Storbeck and Clore, 2008), additionally indicating that a negative mood may at the same time leave perceptual processing intact (Sakaki et al., 2011). In three semantic categorisation and perceptual experiments, Sakaki et al. (2011) examined how picture-induced positive, negative, and neutral moods alter the speed and accuracy of binary semantic judgements about (un)related word pairs in an SCT as well as binary perceptual judgements (i.e., judging the colour/shade of individual letters). Overall, Sakaki et al. (2011) observed slower RTs in SCTs in the negative compared to positive and neutral mood conditions, pointing again to an inhibitory effect of a negative mood on activation spread in semantic memory. They also suggested that the observed task-dependent differences may point to a negative mood interfering with the activation of verbal working memory, imposing higher cognitive demands. Yet, there were no between-mood differences in the perceptual tasks, irrespective of their difficulty, indicating no behavioural mood effect on attention.

In contrast, behavioural research employing semantic priming has also suggested that a negative mood may actually promote systematic (i.e., structured) semantic associations among the concepts in semantic memory (Hesse and Spies, 1996). In an LDT, Hesse and Spies (1996) tested how Velten sentences–induced (i.e., reading and contemplating over self-referential affirmatives evoking a targeted mood state) and music-induced negative and neutral moods influence semantic priming. Besides non-words, they used structured (i.e., based on synonyms and type–token relations), unstructured (i.e., based on idiomatic speech relations), and unrelated prime–target pairs. They also employed a longer stimulus onset asynchrony (SOA) of 500 ms, as it is believed to facilitate controlled and not automatic word processing. Hesse and Spies (1996) found a larger semantic priming effect for the well-structured prime–target pairs in a negative compared to neutral mood, with no between-mood effect for the unstructured pairs. They concluded that a negative mood may direct attention to structured (i.e., systematic) semantic relations between words, facilitating their activation in semantic memory.

Behavioural research has also indicated that a negative mood may promote greater attention to detail and an accommodative processing style (Matovic et al., 2014). Using a free recall paradigm, Matovic et al. (2014) tested how film-induced positive, negative, and neutral moods alternate the speed and accuracy of binary and rating judgements of the clarity of (un)ambiguous sentence pairs and their free recall. They found that the ambiguities were discriminated slower yet with greater precision in a negative compared to positive and neutral mood, with more information also being recalled in a negative compared to positive mood. Of note, a positive mood did not mirror the results observed in a negative mood, and there was no difference between positive and neutral moods.

Finally, behavioural research has also shown that a negative mood may impede predictive sentence processing to a greater extent in older than younger adults (Liu, 2021). Employing a self-paced reading paradigm, Liu (2021) explored how music-induced positive and negative moods affect the accuracy of binary comprehension judgements along with RTs to critical words embedded in highly and lowly predictable sentences in younger (M_{Age} = 19.7 years) and older adults (M_{Age} = 65.9 years). They found that while both younger and older adults effectively discriminated between highly and lowly predictable sentences in a positive mood, such an effect was observed only for younger adults in a negative mood, suggesting that a negative mood impedes language comprehension in older individuals.

Electrophysiological evidence

Accumulating electrophysiological evidence has also pointed to marked mood effects on semantic processes (Chung et al., 1996; Federmeier et al., 2001; Chwilla et al., 2011; Jiménez-Ortega et al., 2012; Pinheiro et al., 2013; Van Berkum et al., 2013; Vissers et al., 2013; Wang et al., 2016; Goertz et al., 2017; Ogawa and Nittono, 2019a,b; Naranowicz et al., 2022b; see also Supplementary materials), yet employing different experimental paradigms than behavioural research. Two ERP components indexing semantic processing have been observed to be particularly sensitive to mood fluctuations: the N400 and the P600 or late positive complex (LPC). The N400 is a negative-going brainwave with a centroparietal scalp distribution and slight right-hemisphere bias, peaking in amplitude between 300–500 ms post stimulus onset (Kutas and Hillyard, 1980). The N400 is typically responsive to semantic violations: more pronounced N400 amplitudes are observed in response to critical words semantically incongruent with a given context (e.g., Moreno and Kutas, 2005), semantically congruent yet implausible in a given context (e.g., Kutas and Hillyard, 1984), and incongruent with one's general world knowledge (e.g., Kuperberg et al., 2003). A linear decline in N400 amplitudes indexes the activation of more predictive mechanisms (i.e., greater expectedness) and, thereby, fewer cognitive resources engaged in lexicosemantic access. This leads to less effortful and, consequently, faster retrieval of word meanings from long-term memory (Kutas and Hillyard, 1980). The LPC (also known as the "semantic P600") is a positive-going brainwave, typically with a parietal scalp distribution and slight left-hemisphere bias, peaking in amplitude at around 500–900 ms (Friedman and Johnson, 2000). Besides its sensitivity to syntactic violations (i.e., "syntactic P600"; Hagoort et al., 1993), the P600/LPC is also responsive to semantic incongruities and expectancies (e.g., Spotorno et al., 2013), with higher P600/LPC amplitudes mirroring the mechanisms engaged in re-analysis and integrating the information retrieved from long-term memory with a broader context (Brouwer et al., 2012).

Early electrophysiological research has suggested that a mild positive mood may facilitate lexicosemantic access to distantly related concepts in semantic memory, at least in females (Federmeier et al., 2001). In a passive reading task, Federmeier et al. (2001) tested how picture-induced mild positive and neutral moods influence the comprehension of sentence pairs with embedded expected words (EWs), within-category violations (WCVs; i.e., unexpected words of the same semantic category), and between-category violations (BCVs; i.e., unexpected words of a different yet semantically-related category). They observed that BCVs elicited the most pronounced N400 amplitudes, followed by WCVs, and finally EWs in a neutral mood. In a positive mood, BCVs elicited a reduced N400 response, eliminating the differences between the two types of violations. Such a pattern thus points to facilitation of lexicosemantic access to distantly related concepts. Crucially, given that the faciliatory effect of a positive mood occurred only in female and not male participants, gender might be a potential moderator of the mood–language interactions (see also Naranowicz et al., 2022a).

In contrast, further electrophysiological evidence has pointed to a positive mood accelerating lexicosemantic access to closely related concepts and a negative mood inhibiting lexicosemantic access to weakly related concepts in males (Pinheiro et al., 2013). Similarly to Federmeier et al. (2001), Pinheiro et al. (2013) studied the relationship between picture-induced positive, negative, and neutral moods and semantic processing in a semantic decision task (SDT; i.e., classifying sentences as meaningful or meaningless), employing EWs, WCBs, and BCWs and focusing on males only. In a neutral mood, Pinheiro et al. (2013) observed a graded effect, with the highest N400 amplitudes evoked by BCVs, followed by WCVs, and finally EWs, similarly to Federmeier et al. (2001). In a positive mood, the N400 amplitudes elicited by EWs and WCVs converged and were both lower than for BCVs, suggesting a positive mood-driven facilitation of lexicosemantic access the words from the same semantic category.

In a negative mood, the N400 amplitudes elicited by BCVs and WCVs converged and were both higher than for EWs, pointing to a negative mood-driven impairment of lexicosemantic access to the words belonging to different semantic categories. Pinheiro et al. (2013) also observed attenuated N400 responses to EW in a negative compared to positive mood, suggesting that a negative mood may promote the generation of narrowed predictions that may sensitise us to the most relevant contextual information yet not to the relationship between different concepts in semantic memory.

Other electrophysiological evidence has also pointed to qualitative differences in positive and negative mood effects on semantic processing (i.e., mood-dependent processing), instead of the activation of mood-driven facilitatory or inhibitory mechanisms (Chwilla et al., 2011). In a passive reading study, Chwilla et al. (2011; see also Dwivedi and Selvanayagam, 2021 for corroborative evidence regarding dispositional affect) investigated the effects of film-induced positive and negative moods on the comprehension of neutral sentences, containing high- and low-cloze words (i.e., highly expected and rather unexpected words, respectively). They found an attenuated N400 cloze probability effect (i.e., a difference in N400 amplitudes between high and cloze probability conditions) in the negative compared to positive mood condition: while the N400 effect was broadly and bilaterally distributed in a positive mood, it was constrained to the right hemisphere and the left occipital and temporal sites in a negative mood. The N400 effect size correlated positively with participants mood ratings. The results indicate that, instead of facilitating/hindering meaning-related cognitive processes (e.g., motivation or attention), mood may lead to qualitatively different processing strategies, activating heuristics-based and detail-oriented processing modes in a positive and negative mood, respectively. Additionally, low- relative to high-cloze probability sentences elicited more pronounced P600/LPC amplitudes in a negative mood only, suggesting that semantically anomalous information is re-analysed probably due to a negative mood triggering local, detail-oriented processing.

Some electrophysiological research has also shown that mood effects on lexicosemantic access may be dependent on the allocation of attentional resources, with a positive mood triggering selective attention to the most relevant information and a negative mood non-selective attention to all semantic relations (Wang et al., 2016). Combining a passive reading task with an SDT, Wang et al. (2016) looked into how odour-induced positive and negative mood regulated the processing of question-answer pairs, manipulating their semantic congruity (i.e., whether critical words were semantically congruent with the question context) and task-relevance (i.e., whether critical words were relevant to questions or not). They found that while incongruent words elicited larger N400 amplitudes than congruent ones regardless of task-relevance in a negative mood, such an N400 congruity effect was observed only for task-relevant words in a positive mood. These results can be accounted for by a mood-triggered attentional shift during lexicosemantic access: while language users experiencing a positive mood seem to allocate their attentional resources to the most relevant contextual information, a negative mood may trigger non-selective and analytical information processing, directing equal attention to semantic relations among all words, regardless of whether they are critical to a given context or not.

Electrophysiological evidence has also suggested that a positive compared to negative mood may promote reliance on general knowledge structures (i.e., heuristics), leading to increased cognitive effort invested in semantic integration and re-evaluation (Vissers et al., 2013). Vissers et al. (2013) tested how film-induced positive and negative moods influence the processing of semantically plausible and implausible (i.e., conflicting with general world knowledge) sentences. Though they observed no N400 modulations by mood, implausible sentenced elicited larger P600/LPC amplitudes than plausible sentences in a positive but not in a negative mood. The P600/LPC effect size correlated positively with participants mood ratings. With no mood-dependent differences during the lexicosemantic access stage (indexed by N400 responses), these results again point to the activation of mood-dependent processing modes during semantic re-analysis, with a positive mood reinforcing global heuristics-based processing and a negative mood promoting local detail-oriented one. An alternative explanation offered by Vissers et al. (2013) was that people in a positive mood may be more attentive to semantic anomalies and/or better motivated than those in a negative mood. Interestingly, they also found a left-lateralised effect contrasting with the P600 (i.e., an anterior negativity) in a negative mood only, suggesting that a negative mood may increase working memory demands.

Recent electrophysiological research has offered corroborative evidence for reliance on heuristics in a positive mood during meaning integration, additionally pointing to similar mood-driven mechanisms being activated during native (L1) and non-native (L2) language processing (Jankowiak et al., 2022). In an SDT, Jankowiak et al. (2022) explored how film-induced positive and negative moods influence creative meaning processing in proficient Polish–English bilinguals, presenting participants with words embedded in literal, anomalous, and novel metaphoric sentences. Unlike in Naranowicz et al. (2022b), the anomalous sentences were built based on general knowledge violations. Jankowiak et al. (2022) observed expected higher P600/LPC amplitudes to anomalous compared to both novel metaphoric and literal sentences in a positive mood, suggesting that general knowledge violations required increased semantic integration and re-analysis, irrespective of language of operation. Yet, there were no differences in P600/LPC responses between the three sentence types in a negative mood, suggesting that a negative mood may promote more attentive and detail-oriented processing, decreasing reliance on heuristics.

Similarly, other electrophysiological evidence has also suggested that a negative mood may impede heuristics-based anticipatory mechanisms (Van Berkum et al., 2013). In a passive reading experiment, Van Berkum et al. (2013) researched film-induced positive and negative mood effects on referential anticipation employing short stories with bias-consistent (i.e., confirming) and bias-inconsistent (i.e., disconfirming) expectations about pronouns referring to a first- or second-mentioned character. They found that bias-consistent relative to bias-inconsistent pronouns elicited a larger ERP positivity in the 400–600 ms time window in a positive mood, with no such an ERP pattern in a negative mood. These results evince that a negative mood may impede associative retrieval from long-term memory, possibly mediated by increased inhibitory control. Alternatively, the results may also be accounted for through a bio-energetic perspective (Zadra and Clore, 2011), whereby a negative mood may hinder exploratory behaviour, including some aspects of meaning-related anticipatory processes (e.g., referential anticipation).

Finally, electrophysiological research on the mood–language interactions has recently been extended to the bilingual context (Kissler and Bromberek-Dyzman, 2021; Naranowicz et al., 2022b; Jankowiak et al., 2022; see also Naranowicz et al., 2022a), demonstrating that positive and negative moods may differently affect consecutive stages of L1 and L2 processing (Naranowicz et al., 2022b). In an SDT, Naranowicz et al. (2022b) explored how film-induced positive and negative moods affect bilingual language processing in Polish–English bilinguals, who made meaningfulness judgements on words embedded in meaningful (i.e., expected) and meaningless (i.e., rather unexpected) sentences. First, Naranowicz et al. (2022b) observed that a positive mood may lead to increased attentional focus, irrespective of language of operation, as indexed by higher P1 (i.e., a marker of pre-lexical perceptual processing modulated by attention) amplitudes in a positive compared to negative mood. Second, they also found that a negative mood may promote detail-oriented processing of lexical information in a language requiring in a given moment higher cognitive demands. This was marked by two mirrored ERPs patterns: a reduced N1 (i.e., a marker of early lexical access) response in a negative compared to positive mood in L2 only together with a reduced N2 (i.e., a marker of early lexicosemantic processing) response in a negative compared to positive mood in L1 only. Third, Naranowicz et al. (2022b) also found a facilitatory effect of a positive mood on lexicosemantic processing, yet only in the L1 context. This was indexed by an increased N400 response to meaningless compared to meaningful sentences in a positive mood in L2, with no such a difference in L1 in a positive mood. Finally, they also found that a negative mood may temporarily suppress full semantic integration of L2 content, likely to "protect" bilinguals from adverse effects of a negative mood (see Wu and Thierry, 2012). This was marked by an increased P600/LPC response to L2 than L1 meaningful sentences in a negative mood only.

General discussion

Theoretical considerations

Theoretical modelling has a high epistemic value, providing researchers with explanatory insights into observable phenomena. The above reviewed theoretical accounts delineating mood effects on cognitive mechanisms have conjured up a complex yet rather consistent picture. Overall, such frameworks predict that mood functions as a biological marker – an embodied source of information about one's current state of mind, activating context-dependent cognitive strategies (i.e., mood-dependent processing). Therefore, its adaptational role is to help us adapt our behaviour in socially complex situations by tuning numerous cognitive mechanisms.

The reviewed theoretical models have together revealed that mood may affect four different cognitive faculties: perception, attention, motivation, and exploration tendencies. Crucially, research on the mood–language interactions has offered some empirical support for some of them. First, mood has been hypothesised to modulate *perception*: positive and negative moods may, respectively, increase reliance on already stored general knowledge (i.e., heuristics-driven, assimilative and relational thinking) and analysis of environmental stimuli (i.e., accommodative and referential thinking; e.g., Schwarz and Clore, 1983; Bless, 2001; Bless and Fiedler, 2006; *cf.* Herz et al., 2020). Such predictions have gained support in both behavioural (Bless et al., 1996) and electrophysiological research on the mood–semantics interactions (Van Berkum et al., 2013; Vissers et al., 2013; Jankowiak et al., 2022). An important observation may be that the predictions of perception-oriented models might be testable when information typicality/relevance (Bless et al., 1996), cognitive biases (Van Berkum et al., 2013), and general knowledge violations (Vissers et al., 2013; Jankowiak et al., 2022) are manipulated. Second, mood has been argued to regulate *attention*: positive and negative moods are, respectively, associated with global (i.e., top-down and broad) and narrow (i.e., bottom-up, local, and detail-oriented) attentional focus (e.g., Schwarz and Clore, 1983; Herz et al., 2020). These predictions are rather consistent with the reviewed behavioural (Bless et al., 1996; Rowe et al., 2006; *cf.* Sakaki et al., 2011) and electrophysiological evidence (Naranowicz et al., 2022b). It is noteworthy, however, that these studies drew conclusions about the breadth of attentional focus based on their findings from perceptual tasks (Bless et al., 1996; Rowe et al., 2006) or the pre-lexical stage of visual word processing (Naranowicz et al., 2022b), suggesting that research on semantic processing alone may not deepen our understanding of mood effects on attention to a great extent. Third, mood has also been hypothesised to affect *motivation*: a positive mood signals cognitive ease (i.e., effortless processing) and a need for maintenance of such a favourable state, whereas a negative mood marks cognitive difficulty (i.e., vigilant and effortful processing) and a need for one to improve their state of mind (e.g., Clark and Isen, 1982; Schwarz and Clore, 1983; Schwarz, 1990, 2002). While some researchers interested in the mood–semantics interactions have speculated that positive mood-driven facilitatory effects on semantic processing might be correlated with increased motivation (Van Berkum et al., 2013; Vissers et al., 2013), it appears that none of them have tested potential mood-dependent motivation effects in a systematic way. Fourth, mood has been anticipated to regulate *exploration tendencies*: positive and negative moods prompt exploratory or exploitatory behaviour, respectively (e.g., Zadra and Clore, 2011; Herz et al., 2020). Similarly to the motivation-oriented frameworks, this approach has not been addressed in research on the mood–semantics interactions in a systematic way. Still, Van Berkum et al. (2013) suggested that a negative mood may impair openness to exploratory processing, impeding heuristic anticipation.

Crucially, the available theoretical frameworks have not been oriented towards the role of mood in semantic processing, a notable exception being the ALC model offered by van Berkum et al. (2018; Van Berkum, 2019), which still only acknowledges a mediating role of the recipient's mood in understanding messages from interlocutors. Observably, most behavioural and electrophysiological evidence has concentrated on how mood inhibits/impairs information retrieval from semantic memory and the relationships among concepts in it (e.g., Rowe et al., 2006; Storbeck and Clore, 2008; Chwilla et al., 2011; Naranowicz et al., 2022b). With accumulating evidence on mood effects on semantic memory organisation, future research could also concentrate on how to incorporate one's mood state into theoretical models of semantic memory (see Kumar, 2021 for a review).

It is also noteworthy that, while most theoretical accounts somewhat complement one another, the SoM framework (Herz et al., 2020) seems to contradict earlier accounts in terms of its predictions about the mood–perception interactions. Specifically, in contrast to earlier theoretical frameworks (e.g., Schwarz and Clore, 1983; Bless, 2001; Bless and Fiedler, 2006), Herz et al. (2020) proposed that an increase in one's mood is, among others, accompanied by increased reliance on sensory information (i.e., a broader SoM) whereas a decrease in mood with increased reliance on predictions (i.e., a narrower SoM). While the relationships between most dimensions in the SoM framework were hypothesised based on previous empirical work, Herz et al. (2020) did not actually offer much corroborative evidence to support such a mood–perception dependency. In fact, besides contradicting previous theoretical accounts, such a pattern does not seem to find much support in the discussed research on semantic processing, indicating that it is a positive and not negative that promotes reliance on previous knowledge and predictions (e.g., Chwilla et al., 2011; Van Berkum et al., 2013; Vissers et al., 2013). Moreover, moving beyond language research, increased reliance on pre-existing knowledge (e.g., cognitive biases) in a positive and not negative mood has also been observed in other domains (see Forgas, 2017 for a review). For instance, employing a shooter bias paradigm, Unkelbach et al. (2008) found that individuals in a positive mood may display increased aggressive tendencies towards Muslims (i.e., the *turban effect*) compared to those in a negative mood. Surprisingly, however, Herz's et al. (2020) predictions about the other state of mind dimensions (i.e., attention, thought, and openness to experience) are still consistent with the earlier theoretical accounts – they proposed that a positive mood may be associated with a global attentional focus, broader associative thinking, and exploratory tendencies whereas a negative mood with a local attentional focus, narrow accommodative thinking, and exploitatory tendencies (e.g., Schwarz and Clore, 1983; Bless, 2001; Zadra and Clore, 2011). Therefore, though the SoM framework (Herz et al., 2020) offers a comprehensive view on the role of mood in one's overall state of mind, its predictions about the mood–perception relationship does not seem to be sufficiently supported by previous research and should be interpretated with caution.

Methodological considerations

To test predictions about mood–language interactions, researchers have elicited positive and negative mood states using a range of MIPs. Affectively evocative film clips appear to be the option of choice in psycholinguistic research due to their high potency. Experimentally induced mood fluctuations have been traditionally measured using self-reports, which coincides with the dimensional (e.g., Russell, 1980) and distinct-state (e.g., Izard, 1993) approaches to affective constructs. Although easy to administer, such measures are subject to a number of measurement issues that may question their reliability, such as the social reliability bias, obeying demand characteristics, or variations in participants' intrapersonal skills.

Arguably, a critical methodological issue concerning experimental mood elicitation is the selection of an effective measure of mood change. Ekkekakis (2013) argued that a measure of an affective construct of interest (i.e., core affect, mood, or emotion) should be consistent with a theoretical framework upon which the measure was built. For instance, adopting the dimensional approach to mood would necessitate using bipolar mood valence (i.e., positive––negative) and arousal (calm––excited) scales to measure experimentally induced mood changes. While such a consistency-driven perspective is reasonable, it could also be justifiable, if not recommended, to adopt a more practical perspective: employing a broader spectrum of mood measurements in research involving positive and negative mood elicitation. The revised literature suggests that, when implemented through standardised procedures, elicitation of positive and negative moods typically affects participants' mood ratings in a predictable manner. Specifically, when a bipolar mood valence scale (i.e., positive––negative) is adopted, it is reasonable to expect an increase/no change in mood ratings post relative to pre mood induction in the positive mood condition and their decrease in the negative mood condition (e.g., Wang et al., 2016). An analogous pattern expected for two unipolar scales is a negative correlation between mood ratings in both mood conditions: higher mood ratings post mood induction on the positive mood/happiness scale are typically accompanied by lower mood ratings on the negative mood/sadness scale in the positive mood condition, with the reversed pattern in the negative mood condition (Joseph et al., 2020). An additional use of such unipolar scales would help researchers better understand the relationship between positive and negative moods elicited *via* MIPs. For instance, it is probable that decreased mood ratings on a bipolar scale are reflective of a decreased positive mood without increasing a negative mood (see Joseph et al., 2020), which could significantly change the interpretation of observed mood effects on cognitive processes. Furthermore, even when mood induction aims to elicit general positive and negative moods, individual mood-inducing stimuli could evoke discrete affective states of varying intensity due to their individual characteristics or participants' personal associations. Therefore, it seems also reasonable to supplement bipolar and unipolar scales with a mood-related questionnaire targeting discrete positive and negative emotions, which may again help mood researchers better understand the complexity of the affective states evoked by their mood manipulation (e.g., Naranowicz et al., 2022a,b).

Nevertheless, given the elusive nature of our affective states, it is difficult, if at all possible, to objectively and accurately measure participants' current mood. Mood researchers could also benefit greatly from employment of various physiological measures (e.g., heart rate variability or skin conductance responses) to measure participants' reactivity to mood-inducing stimuli in a more objective fashion (e.g., Engelbregt et al., 2022; Sterenberg Mahon and Roth, 2022). For instance, electrodermal activity measures (e.g., skin conductance responses) have been used as a physiological marker of changes in the sympathetic nervous system reflecting one's emotional arousal (see Behnke et al., 2022 for a review).

Behavioural and electrophysiological evidence

Behavioural research has pointed to differences in how positive and negative moods affect semantic processes, concentrating mostly on semantic memory organisation, reliance on pre-existing knowledge, and attentional focus. Specifically, a positive mood has been observed to facilitate the spread of activation to close associates (Hänze and Hesse, 1993) and/or remote associates (Bolte et al., 2003) in semantic memory. Such a favourable mood state has also been associated with a greater breadth of attentional selection (i.e., a global attentional focus; Rowe et al., 2006) as well as reliance on general knowledge structures (i.e., heuristics) due to increased cognitive ease (i.e., effortless processing; Bless et al., 1996). In contrast, a negative mood has also been linked to dampened activation of semantic associations in semantic memory (Storbeck and Clore, 2008; Sakaki et al., 2011), which might actually be limited to close associates (Bolte et al., 2003), as well as decreased breadth of attentional selection (i.e., a local attentional focus; Rowe et al., 2006). A negative mood has also been linked to impeded sentence comprehension particularly in older relative to younger adults (Liu, 2021). On the other hand, a negative mood has also been found to facilitate responses to systematic stimuli requiring controlled processing (Hesse and Spies, 1996) and result in greater attention to detail and an accommodative processing style (Matovic et al., 2014).

Similarly to behavioural investigations, electrophysiological research has also pointed to marked between-mood differences in semantic processing, offering explanations based on attention, motivation, and processing strategies. A positive mood has been linked to facilitated lexicosemantic access to both distantly related concepts (i.e., between-category violations; Federmeier et al., 2001) and those belonging to the same semantic category (i.e., within-category violations; Pinheiro et al., 2013). It has also been associated with the activation of a global, heuristics-based processing style during lexicosemantic access (Chwilla et al., 2011) and semantic re-analysis (Vissers et al., 2013). It is noteworthy that this effect may be limited to bilinguals' native language only (Naranowicz et al., 2022b) and observed mostly in females rather than males (Federmeier et al., 2001; see also Naranowicz et al., 2022a). Others have also suggested that a positive relative to negative mood may lead to increased motivation (Vissers et al., 2013) along with allocation of attentional resources to the most relevant contextual information (Vissers et al., 2013; Wang et al., 2016). In contrast, being in a negative mood may result in increased sensitivity to contextual information due to the activation of detail-oriented processing (Pinheiro et al., 2013), especially during semantic re-analysis (Chwilla et al., 2011; Vissers et al., 2013; Wang et al., 2016), inhibition of associative retrieval from long-term memory (Van Berkum et al., 2013), and increased working memory demands (Vissers et al., 2013).

Together, the discussed behavioural and electrophysiological evidence has demonstrated that positive and negative moods differently affect semantic processes, which is consistent with a common finding that these two mood states promote different cognitive strategies (i.e., mood-dependent processing styles; see Forgas, 2017 for a review). However, the reviewed literature has also revealed a number of discrepancies in empirical findings, which may somewhat distort this clear picture.

First, while a positive mood has been observed to exert an overall facilitatory effect on semantic processes, it remains unclear if closely and remotely associates are affected by it to the same degree. Specifically, Hänze and Hesse (1993) observed a facilitative impact of a positive mood on spreading activation to close yet not remote associates, whereas Bolte et al. (2003) observed such a pattern for remote associates. Such a discrepancy could be accounted for by methodological differences: Hänze and Hesse (1993) employed a semantic priming paradigm, relying on RTs in an LDT, and Bolte et al. (2003) employed a remote association paradigm, relying on the accuracy of intuitive coherence judgements in a remote association task. Interestingly, a similar discrepancy can also be observed in electrophysiological research. Federmeier et al. (2001) found a facilitatory effect of a positive mood on lexicosemantic access to remote associates (i.e., a reduced N400 response to BCVs in a positive relative to neutral mood), whereas Pinheiro et al. (2013) to close associates (i.e., a reduced N400 response to WCVs in a positive relative to neutral mood). Pinheiro et al. (2013) suggested that the differential mood effects observed in the two studies may have been driven by stimuli (different items), MIP (i.e., presentation of many emotional pictures at once vs. one picture before each sentence), gender (females vs. males), and task instructions (i.e., passive reading vs. an SDT). It is also noteworthy that the sample sizes in both studies were rather limited: Federmeier et al. (2001) recruited 11 female participants and Pinheiro et al. (2013) 15 male participants. Hence, future research on mood–language interactions could benefit greatly from a replication-oriented approach. The studies reviewed above have employed the whole spectrum of semantically oriented tasks as well as mood-inducing and linguistic stimuli. On the one hand, this approach is advantageous seeing that each study broadens our knowledge about mood–language interactions. On the other hand, numerous procedural differences make it impossible to draw valid conclusions, including those about mood effects on remote and close associates. Whenever possible, it would be beneficial to undertake conceptual replications (i.e., changing only one dimension).

Second, another inconsistency observed in electrophysiological research concerns the mood-driven N400 amplitude changes. While many researchers have observed facilitatory effects of a positive mood on lexicosemantic access, as marked by the N400 amplitude changes (Federmeier et al., 2001; Chwilla et al., 2011; Pinheiro et al., 2013; Wang et al., 2016; Naranowicz et al., 2022b), others have actually failed to observe any mood-driven modulations in the N400 time frame (Jiménez-Ortega et al., 2012; Vissers et al., 2013; Goertz et al., 2017; Ogawa and Nittono, 2019b; Jankowiak et al., 2022). Such a null mood effect may be linked to the lexicosemantic mechanisms of interest (i.e., semantic plausibility vs. expectancy). For instance, both Vissers et al. (2013) and Jankowiak et al. (2022) built the semantically implausible sentences based on general world knowledge violations (i.e., unexpected and completely implausible sentences), whereas others have mostly employed the semantic anomalies based on expectancy (i.e., unexpected yet not entirely implausible sentences; e.g., Federmeier et al., 2001; Chwilla et al., 2011; Naranowicz et al., 2022b). Another reason for no mood effect on lexicosemantic access may be related to the use of weak/ineffective MIP. For instance, Jiménez-Ortega et al. (2012) found no mood effects in both the N400 and LPC time frames, concluding that the employed mood-inducing short written stories (i.e., four-sentence paragraphs) could have been of insufficient power to elicit significant mood effects. Using the experimental paradigms indirectly related to lexicosemantic processes may also be another reason for finding no mood effects in the N400 time window (Goertz et al., 2017; Ogawa and Nittono, 2019b). For instance, Ogawa and Nittono (2019b) explored how positive and negative moods affect subjective imaginability ratings and found no mood effects on the N400 and N700 components, explaining that such a null effect may be linked to the employment of a rating task instead of a binary decision–based task or decontextualized words instead of the words embedded in sentential contexts.

Third, previous research on the mood–language interactions has also produced somewhat inconsistent results regarding the breadth of attentional focus. Previous studies have pointed to increased breadth of attentional focus in a positive mood, which can also be narrowed in a negative mood (see Moriya and Nittono, 2011 for a review). Such a pattern is consistent with previous theoretical models (e.g., Schwarz and Clore, 1983; Zadra and Clore, 2011; Herz et al., 2020), and it has also been observed in the reviewed literature (Bless et al., 1996; Rowe et al., 2006; Naranowicz et al., 2022b). For instance, Rowe et al. (2006) observed slower RTs to incompatibility trials (i.e., strings of letters with one different letter) in a positive relative to neutral and negative mood in a Flanker task. They concluded that a positive mood may impair the selective visuospatial attention as a result of eased inhibitory control and, consequently, a broader attentional focus. Similarly, Naranowicz et al. (2022b) found a larger P1 (i.e., a marker of early sensory processing modulated by attention) response to words in a positive compared to negative mood, also associating such an effect with broadened attentional focus in a positive mood (see Moriya and Nittono, 2011 for corroborative evidence from a Flanker task). In contrast, Sakaki et al. (2011) found slower RTs to word pairs in an SCT, with no between-mood difference in perceptual tasks (i.e., judging the colour/shade of the first letter), concluding that a negative mood impedes semantic processing to a greater extent than perceptual processing. Yet, one could argue that Sakaki et al. (2011) study may not be suitable for drawing such conclusions, as the predictions about mood-driven attentional focus are typically tested using global–local visual processing paradigms (Moriya and Nittono, 2011). Moreover, Sakaki et al. (2011) also employed longer SOA of 1,300 ms, promoting controlled rather than attentional effects. Therefore, it appears that a negative mood does not necessary impairs semantic processing to a greater extent than perceptual processing, as suggested by Sakaki et al. (2011), and more research is needed to corroborate this finding.

Finally, another unresolved question is whether a negative mood sensitises us to contextual information. Besides pointing to an inhibitory effect of a negative mood on lexicosemantic access (i.e., impaired sensitivity to the relationship between concepts in semantic memory), Pinheiro et al. (2013) also suggested that a negative mood may lead to narrowed context-specific predictions, possibly being indicative of negative mood–driven selective attention. In contrast, Wang et al. (2016) suggested that a positive mood may promote selective attention to the most relevant contextual information, whereas a negative mood may promote non-selective attention to all semantic relations. Based on such findings, one could tentatively conclude that a negative mood may promote selective attention when expected semantic information is processed (as in Pinheiro et al., 2013) and non-selective attention in the presence of semantic violations (as in Wang et al., 2016). Yet, bearing in mind that the two findings have not yet been replicated by other ERP studies as well as numerous methodological differences between the two studies, more research is needed to answer the question whether and how a negative mood promotes (non-)selective contextual sensitivity.

Regarding the methodological considerations, behavioural and electrophysiological research has targeted mood–semantic processing interactions and mostly reached comparable conclusions, but these two bodies of research have focused on distinct aspects of semantic processing and employed dissimilar experimental paradigms. Namely, behavioural research has mostly investigated mood effects on semantic memory structure and spread of activation as indexed by RTs, response accuracy, and information recall, manipulating semantic relatedness, congruity, and categories mostly at a word level (e.g., Storbeck and Clore, 2008). In contrast, electrophysiological research has mostly concentrated on mood effects on lexicosemantic access and semantic re-evaluation (i.e., two consecutive meaning-related stages of visual word processing), as indexed by N400 and LPC modulations, manipulating semantic congruity and plausibility primarily at sentence and discourse levels (e.g., Chwilla et al., 2011). Behavioural research on mood–language interactions appears to slowly transition to electrophysiological research. This seems to be a natural direction since behavioural measures have known limitations due to response latencies and accuracy reflecting the end product of the whole meaning-driven decision-making process (Liu, 2021), whereas ERP components can index online brain activity changes throughout the full time-window of processing. To test the reliability and validity of the behavioural findings and to provide a fresh perspective on them, future work could adopt, for instance, the semantic priming (e.g., Sakaki et al., 2011) or remote association (e.g., Rowe et al., 2006) paradigms in ERP experiments.

It is also noteworthy that there have emerged two approaches to interpreting the N400 modulations by mood. A linear decline in the N400 amplitudes is typically interpreted as indicative of enhanced lexicosemantic access, which translates into facilitated retrieval of word meaning from long-term memory due to increased cognitive ease and the activation of more predictive mechanisms (e.g., Kutas and Hillyard, 1980). Consequently, most researchers have interpreted a decrease in N400 amplitudes/a smaller N400 effect in a positive compared to neutral and/or negative mood as indicative of positive mood–driven facilitation of lexicosemantic access (e.g., Federmeier et al., 2001; Pinheiro et al., 2013; Naranowicz et al., 2022b). Chwilla et al. (2011), however, observed a broadly and bilaterally distributed N400 effect in a positive mood, with its significant reduction to the right hemisphere and the left occipital and temporal sites in a negative mood. Consequently, Chwilla et al. (2011) proposed an alternative approach, whereby mood-dependent effects on lexicosemantic access are reflected in the N400 effect distribution instead of the N400 amplitude changes.

Speculatively, a potential cause of the frequently reported dichotomous mood-dependent processing styles may also be rooted in the "file drawer" phenomenon – a common scientific practice of not publishing research producing null results (Mervis, 2014). There may thus be evidence pointing to similarities between positive and negative mood effects on semantic processing which has never been published. Ogawa and Nittono (2019a,b), for instance, looked at positive and negative moods influences on word imagery processing, as indexed by N400 and N170 components as well as RTs. With the exception of one main effect of mood (i.e., a larger N400 response in a positive than negative mood), both studies failed to reveal any differential effect of mood, despite adopting standardised experimental procedures for mood research and sufficient sample size. Ogawa and Nittono (2019a,b) research represents desirable practice that may help the scientific community counteract the current *replication crisis* (see Shrout and Rodgers, 2018, for a review) and potentially shed a fresh light on research on mood–language interaction: the authors made their unpublished manuscript available online, pre-registered their follow-up study, calculated their sample size in advance, and shared their primary data.

Other future research directions

One of the outstanding questions in mood research concerns the possibility of gender differences in mood–language interactions. Federmeier et al. (2001) was the first to report a stronger facilitatory effect of a positive mood on semantic processing in females than males, which was later corroborated in a recent behavioural study (Naranowicz et al., 2022a). Such a female advantage in a positive mood may possibly be explained by greater sensitivity to emotions (e.g., Goldstein et al., 2001) or increased physiological reactivity to affective stimuli (e.g., Bianchin and Angrilli, 2012; Naranowicz et al., 2022a). Moreover, given that females are stereotypically perceived as more emotional than males (e.g., Fischer, 1993), they might even be more susceptible to mood induction due to a social desirability bias (i.e., they might believe that this is a socially expected behaviour from them). It is noteworthy that many studies discussed above have in fact concentrated on female participants only (e.g., Chwilla et al., 2011; Van Berkum et al., 2013; Vissers et al., 2013; Wang et al., 2016; Jankowiak et al., 2022; Naranowicz et al., 2022b), indicating that mood and affective research itself may be somewhat biased towards testing or reporting data from the female population only. More attention should therefore be devoted to cross-sex comparisons to better understand the potential mood–gender interactions in linguistic research and to make observed findings more generalisable. Also, future research could benefit from approaching gender as a non-binary social construct, especially given that non-binary persons constitute a marginalised and under-researched population (e.g., Richards et al., 2016).

Another outstanding question in the mood–language literature is the practical implications of previous empirical evidence, particularly in the case of psychotherapy, interpersonal communication, education, mediation, and negotiation. For instance, one could expect that our current mood may influence communicative interactions. Specifically, while being in a good mood may potentially improve overall comprehension of the messages communicated to us, it may also make us think more stereotypically, leading to potential misunderstandings. Then, being in a negative mood may excessively direct our attention to details during communicative encounters, making us miss a bigger picture. Another interesting example is psychotherapy. Though the reviewed literature did not regard clinical populations, one could expect individuals with depression to benefit greatly from talking about their emotions in their L2 when they are unable to communicate them freely in their L1 (Naranowicz et al., 2022b).

Conclusion

The discussed theoretical frameworks have offered rather consistent predictions about how mood affects perception, attention, motivation, and exploration tendencies. The reviewed behavioural and electrophysiological research has provided the greatest empirical support for the perception-oriented accounts.

The present paper reviewed research on positive and negative mood effects on semantic processing so as to offer some future research directions. First, while the discussed perception- and attention-oriented theoretical frameworks have found empirical support in research on mood and semantic processing (e.g., Jankowiak et al., 2022; Naranowicz et al., 2022b), there is a need for incorporating mood into semantic memory-oriented models. Second, it would be reasonable to employ a broader spectrum of mood measures when eliciting positive and negative moods, which would help understand the dynamics of participants' affective states. Third, because of the discrepancies in the observed findings, more scholarly attention should be devoted to the questions of how mood affects close and remote associates in semantic memory (e.g., Federmeier et al., 2001; Pinheiro et al., 2013), lexicosemantic access as indexed by the N400 amplitude changes (e.g., Chwilla et al., 2011; Ogawa and Nittono, 2019b), attentional breadth (e.g., Rowe et al., 2006; Sakaki et al., 2011), and (non-)selective contextual sensitivity (e.g., Pinheiro et al., 2013; Wang et al., 2016). Fourth, a replication-oriented approach could be advantageous to research on mood–semantic processing interactions in order to account for some unanticipated results. Finally, the frequently reported dichotomous mood-dependent processing styles could potentially result from a publication bias, and good research practices such as pre-registration could help researchers identify potential similarities between positive and negative moods effects on semantic processing.

Author contributions

MN contributed to conceptualisation as well as manuscript writing and revision.

Funding

This work was funded by the National Science Centre, Poland (Grant No 2018/31/N/HS2/00120) awarded to MN.

Acknowledgments

I would like to express a deep sense of gratitude to my PhD supervisors – prof. Katarzyna Bromberek-Dyzman and prof. Guillaume Thierry for sharing their comments on the present review paper with me.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1014706/full#supplementary-material

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