Love and War Across Languages

Auditory Processing of Emotion Words in Dutch-English Bilinguals

by

Merel Vermeer
S1037017

MA degree programme in
Linguistics and Communication Sciences (research)

Udenhout, 5 April 2026

Supervisor & assessor: Dr. S.M. Brouwer
Co-supervisor & assessor: Dr. S.S. Bultena

Radboud University

Acknowledgements

As I write the acknowledgements, I look back on a period that can be described as a whirlwind. When I began the Research Master's programme, I intended to dedicate myself fully to my thesis, not that I didn't, but the intention was to be free from distractions such as courses or other commitments. In reality, things unfold quite differently.

Eager to begin my second individual EEG study after an exciting time in Poland, I started this project about a year ago. A few months in, however, Susanne and I decided to apply for an NWO PhD grant with Linda and Judith. After successfully passing the first internal round, I spent the Christmas period writing the full grant proposal, which left little time for my thesis. After several rounds of revisions, we made it through the second internal round and are now preparing to present the proposal to the NWO committee in May, for which I am extremely excited! Therefore, my thesis is more than just a final paper; it has been an invaluable learning journey that has inspired me for the future. Now, we must wait and see what the future will bring. In the meantime, I returned to my thesis, and I am very pleased to say that I have finished it!

This thesis not only marks the completion of my Research Master's, but also concludes seven years of dedication to finish my studies to the best of my ability. It has been a long and intense journey, but one that I truly enjoyed. I am especially grateful for the opportunity to design and conduct my own research project as a final piece to conclude my time as a master student. With this in mind, I would like to express my gratitude to several people.

First, I would like to thank Naomi and Nadine, who spent countless hours with me on the 12th floor of the Erasmus building, testing participants from early mornings until late afternoons. Thank you for keeping me sane throughout these days, despite all the people we saw and the electrodes that seemed to have a mind of their own! I would also like to thank the participants who took part in my experiment!

Andrea! I'm glad you visited Nijmegen during your PhD and that we became such good friends. Thank you for listening to my ICA struggles and for discussing all the brain-related aspects of this project with me. Most of all, thank you for being my friend!

Dagmar, thank you for being there for me during this whirlwind period, for giving me the space I needed to finish my thesis, and for supporting me as I follow my dreams. Thank you for always listening patiently to my endless rants and for keeping me motivated!

I am deeply grateful to my parents for their unwavering support and trust in my ability to complete my studies, being there during stressful moments, and for giving me the opportunity to pursue my dreams! I would especially like to thank my mom and dad for always listening to me and for helping me to bring clarity to my thoughts when I needed it.

I would like to thank Sybrine for co-supervising this thesis, and for being available to discuss the challenges of conducting EEG research in the auditory modality. I would also like to thank you once more for supervising my Term Paper. Our conversations always inspired me!

Finally, I cannot complete this thesis without thanking Susanne. Over the past five years, you have supervised my Bachelor's thesis, collaborated with me on multiple projects, and supported my journey as an early-career researcher, both in the Netherlands and in Poland. I am grateful not only for your supervision, but also for the trust you placed in me and the many opportunities you provided for me to grow as a researcher. In particular, I would like to thank you for teaching me to simplify as much as possible, and to use fewer words, which is something I often struggle with... I am very grateful for your help and I hope we can continue working together, fingers crossed on getting the NWO grant!

The journey goes on.

Table of contents

Abstract

Words carry emotional connotations: for instance, *war* is typically perceived as negative, whereas *love* is perceived as positive. For bilinguals, such words are often experienced differently depending on whether they are encountered in a native or a non-native language. Research on emotional language processing has consistently demonstrated reduced emotional engagement in later-acquired languages. However, most research has focused on written stimuli, leaving open the question of how emotional meaning is processed in spoken language.

Using event-related potentials, the present study investigated whether emotional detachment in a non-native language, as observed in the written modality, also occurs in the auditory modality. Thirty-six Dutch-English bilinguals listened to emotional words evoking negative, neutral, and positive feelings in either their native (L1; Dutch) or second (L2; English) language. Participants were asked to categorize whether the word they heard conveyed a negative (e.g., *war*), neutral (e.g., *door*), or positive (e.g., *love*) emotion in the corresponding language.

Results revealed clear language-dependent effects in emotional processing. Behaviourally, negative words were recognized more accurately and faster than positive words in L1, whereas in L2 this effect was attenuated, appearing only as a smaller accuracy advantage with no response time differences. At the neural level, negative words elicited higher late positive complex (LPC) amplitudes than neutral words in both languages; however, this effect was stronger in L1 than in L2. Additionally, while LPC amplitudes were higher for negative than positive words in L1, no valence effect was observed in L2, suggesting reduced emotional sensitivity. Together, these findings extend prior evidence of attenuated emotional responding in L2 to the auditory modality, suggesting that reduced emotional engagement in L2 is a robust phenomenon across modalities.

1. Introduction

Hearing the word *war* in one's native language (L1) typically evokes strong negative emotions such as disgust and misery. Conversely, the word *love* would likely elicit positive feelings such as happiness and peace. In a second language (L2), however, the same words often fail to provoke comparable emotional responses. This suggests that language not only has the capacity to communicate emotional states, it regulates individuals' emotional perceptions and experiences by conveying emotional meaning (Lindquist, 2017, Pavlenko, 2012). Language and the experience of emotions are thus intertwined (Lindquist et al., 2015; Lindquist, 2017).

Emotional language processing has been frequently studied in multilingual populations. Research has demonstrated that language proficiency influences emotional engagement in later-acquired languages (e.g., Caldwell-Harris, 2014; Dewaele, 2010; Pavlenko, 2012). Emotional responses are frequently attenuated when emotional content is presented in an L2 compared to the L1 (e.g., Jończyk, 2016; Tang et al., 2024). Critically, these studies have predominantly focused on written stimuli. Therefore, they fail to capture how individuals process emotional words when presented auditorily. This is noteworthy as individuals acquire their L1 primarily through speech and encounter emotions first in spoken form rather than text in real-world communication (e.g., Harris et al., 2003). Consequently, the question arises how individuals process emotional content when listening to words in an L1 and L2.

To date, it is unknown whether the emotional detachment in L2, as observed in the written modality, extends to the auditory modality. Spoken words are processed more automatically (Holcomb & Neville, 1990) and often elicit stronger emotional responses than written words (Harris et al., 2003; Yao et al., 2023), indicating the importance of investigating emotional language processing in the auditory modality.

The present study addresses this gap by examining whether emotional detachment is present during emotional word processing in an L2 compared to the L1 in the auditory modality. Using an event-related potential (ERP) paradigm, Dutch-English bilinguals performed a valence judgment task, categorizing each word as negative, neutral or positive in either their L1 (Dutch) or L2 (English). This design allows for a direct comparison of emotional engagement across languages during auditory word processing.

2. Theoretical background

2.1 Emotional word processing in L1

Emotional word processing has been extensively investigated over the past decades (for reviews, see Citron, 2012; Kissler et al., 2008; Pavlenko, 2012). Research distinguishes between words that explicitly denote emotional feelings, such as *love* or *fear*, and words that carry acquired emotional connotations without directly referring to specific emotions, such as *success* or *war* (Pavlenko, 2008). The emotional meaning of these words is typically conceptualized along two widely studied dimensions: valence and arousal (Lang et al., 1997; Russell, 1980). Valence refers to the emotional value of a word, indicating whether it is perceived as negative (unpleasant) or positive (pleasant), whereas arousal reflects the degree of emotional intensity a word elicits (Lang et al., 1997; Russell, 2003). Within this framework, research in L1 has consistently shown that emotional words, regardless of valence, elicit faster and more accurate behavioural responses than neutral words (Kanske & Kotz, 2007; Kousta et al., 2009; Vinson et al., 2013).

This processing advantage for emotional words has frequently been interpreted within the framework of *motivated attention*, which posits that emotional information possesses greater motivational relevance (Bradley, 2000; Lang et al., 1997). Because motivational relevance determines the allocation of attentional resources towards a given stimulus, emotionally salient words may capture attention more readily than neutral stimuli. The allocation of attention to emotionally evocative stimuli reflects the activation of the brain's defensive and appetitive motivational systems. These systems orchestrate responses in two classes of stimulus input: negative emotions engage defensive motivational systems, while positive emotions evoke appetitive tendencies (Chen & Bargh, 1999; Lang, 2000). Consequently, evidence suggests that they evoke differential behavioural and neural responses (Cacioppo & Berntson, 1994, 1999; Ito et al., 1998; Ito & Cacioppo, 2000).

Asymmetries in the processing of negative and positive words have been described as '*negativity bias*' or '*positivity offset*' (Ito et al., 1998; Kauschke et al., 2019; Peeters & Czapinski, 1990). A '*negativity bias*' refers to enhanced attention and stronger emotional responses to negative stimuli (e.g., Baumeister et al., 2001; Carretié et al., 2008b, Delaney-Busch et al., 2016; Nasrallah et al., 2009). In contrast, a '*positivity offset*' reflects the opposite pattern; facilitated processing of positive information (e.g., Bayer & Schacht, 2014; Herbert et al., 2006; Kanske & Kotz, 2007; Kissler et al., 2007; Palazova et al., 2011; Unkelbach et al., 2008; Yang et al., 2013). Accordingly, the '*negativity bias*' is of greater relevance since the rapid detection and avoidance of negative stimuli is critical for survival (e.g., Baumeister et al., 2001). Negative words tend to attract greater attention and are weighted more heavily, provoking a survival instinct to either flee or freeze (Estes & Adelman, 2008; Estes & Verges, 2008; Kauschke et al., 2019; Pratto & John, 1991). This bias may therefore result in faster behavioural responses to negative stimuli, or conversely, it may make it more difficult to withdraw attention, leading to delayed behavioural responses (e.g., Estes & Verges, 2008; Kauschke et al., 2019; Pratto & John, 1991; Rothermund et al., 2001; Taylor, 1991). Attentional vigilance thus provides a comprehensive explanation of the underlying mechanisms of valence in emotional processing.

Electrophysiological measures, particularly event-related potential (ERP) components, provide neural evidence with a high temporal resolution of how valence modulates attention and emotional processing (e.g., Citron, 2012; Kissler et al., 2008). In written word processing, early ERP components, such as the P1–N1 complex and the early posterior negativity (EPN), index relatively automatic and implicit stages of emotional processing (e.g., Frühholz et al., 2011; González-Villar et al., 2014; Herbert et al., 2006; Hinojosa et al., 2010; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2008; Kissler & Herbert, 2012; Palazova et al.,

2011; Schacht & Sommer, 2009; Zhang et al., 2014). The N400 component reflects lexical-semantic access and integration difficulty (e.g., Citron, 2012; Kanske & Kotz, 2007), while later ERP components, such as the late positive complex (LPC), also termed the late positive potential, capture more explicit emotional processing (e.g., Hajcak et al., 2011; Herbert et al., 2006; Kanske & Kotz, 2007; Kissler et al., 2008; Schacht & Sommer, 2009).

The LPC is particularly sensitive to emotional engagement, typically peaking as a positive deflection between 500 and 800 milliseconds after word onset over centroparietal brain regions (e.g., Carretié et al., 2008a; Citron, 2012; Frühholz et al., 2011; Hajcak et al., 2011; Kissler et al., 2007). It is associated with semantic re-analysis and the allocation of attention to emotional information, reflecting sustained emotional processing (Hajcak et al., 2009; Hinojosa et al., 2010; Naumann et al., 1992). The LPC is affected by the depth of emotional processing, predominantly manifesting in tasks that require explicit, attentive processing of emotional content, such as categorising emotions (Delaney-Busch et al., 2016; Fischler & Bradley, 2006; González-Villar et al., 2014; Schacht & Sommer, 2009; Vélez-Uribe & Rosselli, 2020), or lexical decisions (Carretié et al., 2008a; Kanske & Kotz, 2007).

In monolingual studies, emotional written words reliably elicit larger LPC amplitudes compared to neutral words (Carretié et al., 2008a; Herbert et al., 2008; Hinojosa et al., 2010; Kanske & Kotz, 2007; Kissler et al., 2008; Schacht & Sommer, 2009; for a review, see Citron, 2012). However, valence-specific effects are mixed: some studies report more pronounced LPCs for positive words (Herbert et al., 2006, 2008; Kissler et al., 2008; Zhang et al., 2014), others for negative words (Delaney-Busch et al., 2016; Espuny et al., 2018; Frühholz et al., 2011; Holt et al., 2008; Kanske & Kotz, 2007; Liu et al., 2009; Zhang et al., 2017), while some report comparable responses to positive and neutral words (Espuny et al., 2018; Kanske & Kotz, 2007), or enhanced LPCs for both negative and positive relative to neutral words (Conrad et al., 2011). These differences likely reflect interactions between valence and other lexical factors, such as arousal (e.g., Delaney-Busch et al., 2016; Hinojosa et al., 2010; Ito et al., 1998), word type (e.g., Zhang et al., 2017), concreteness (e.g., Kanske & Kotz, 2007; Yao & Wang, 2014; Yao et al., 2016), as well as task demands (Bayer & Schacht, 2014; Hajcak et al., 2009, 2011; Schacht & Sommer, 2009).

In summary, enhanced LPC amplitudes in response to emotional words indicate that emotional content facilitates processing by engaging the brain's defensive and appetitive motivational systems. Emotional information in words is therefore prioritised during processing compared to neutral words. While the specific contribution of negative versus positive valence remains debated, negative words are frequently considered to capture attention more effectively. Crucially, it remains unresolved whether emotional words capture attention similarly in L2 as in L1, leaving open questions about emotional processing across languages.

2.2 Emotional processing across languages

In today's increasingly multilingual society (Grosjean, 2024), the language in which communication occurs is an important contextual factor that influences the processing and perception of emotional content. Crucially, whether a language user assigns a negative, neutral or positive emotional value to words depends on the context in which emotional content is acquired and processed (Caldwell-Harris, 2014). Words obtain their emotional significance through their acquisition in emotionally salient contexts; the age at which words are acquired and the environment in which they are learned and used, play a decisive role in shaping their emotional impact (Harris et al., 2006; Caldwell-Harris, 2014).

Native languages (L1) are typically acquired in early childhood within emotionally rich communicative environments. Words learned in this context develop a distinct emotional

resonance through repeated exposure across diverse contexts (Altarriba, 2003; Harris et al., 2006). As words learned early in life coincide with the development of emotional regulation systems, L1 acquisition establishes strong links with the amygdala, a brain structure central to emotional processing (Barrett et al., 2007; Bloom & Beckwith, 1989; LaBar & Phelps, 1998). Consequently, L1 emotion words become intrinsically linked to a person's emotional responses, reflecting the integration of linguistic and emotional systems established during early childhood.

Conversely, a later-acquired language, as the L2, is usually learned in formal, emotionally neutral educational settings and primarily utilised in professional contexts (Caldwell-Harris, 2014; Dewaele, 2004, 2010). Without rich emotional contexts, L2 learners may struggle to establish strong, meaningful connections between words and their emotional resonance (Pavlenko, 2012). In addition, given that the brain's emotional regulation system is fully developed by the time an L2 is acquired, weaker connections are established between the brain's language and emotional systems. Consequently, the context of learning and the age of acquisition (AoA) contribute to a greater psychological and cognitive distance in the L2, resulting in diminished emotional intensity relative to the L1 (Imbault et al., 2020; Sugita-McEown et al., 2024).

Consistent with this account, a substantial body of research has demonstrated that emotional reactivity is reduced in L2 compared to L1. Converging evidence has been documented using self-report measures (e.g., Dewaele, 2004; Puntoni et al., 2008), as well as psychophysiological and electrophysiological indices, including pupillometry (e.g., Iacozza et al., 2017; Toivo & Scheepers, 2019), skin conductance responses (e.g., Baumeister et al., 2017; Harris, 2004; Jankowiak & Korpal, 2017), and electroencephalography (EEG; e.g., Jończyk et al., 2016, 2024; Wu & Thierry, 2012; Tang et al., 2024). However, the distinction in emotional responses between L1 and L2 is nuanced. When the L2 is highly proficient or dominant, bilinguals may experience comparable emotional effects in both languages (e.g., Baumeister et al., 2017; Conrad et al., 2011; Degner et al., 2011; Eilola et al., 2007; Ferré et al., 2010; Kazanas & Altarriba 2016; Opitz & Degner, 2012; Ponari et al., 2015; Sutton et al., 2007).

Despite comprehending the semantic meaning of L2 words, bilinguals often report a reduced emotional resonance (Dewaele, 2004, 2008; Ferré et al., 2022; Pavlenko, 2005). L2 processing is frequently described as less embodied, lacking the emotional grounding typically observed in L1 (Pavlenko, 2012; Sheikh & Titone, 2015; Vukovic & Shtyrov, 2014). Accessing the emotional content of L2 words is less automatic and requires greater cognitive effort (Hinojosa et al., 2010; Opitz & Degner, 2012; Segalowitz et al., 2008). This reduced automaticity leads bilinguals to feel less emotionally engaged with L2 words, despite having full semantic understanding. This phenomenon may be particularly relevant in everyday communication, where the rapid succession of words limits the cognitive resources required for accessing a word's emotional value. Consequently, emotional processing in L2 is attenuated.

Overall, language plays a decisive role in determining which emotional experiences are evoked when encountering emotional words. Differences in the embodiment of emotional vocabulary between L1 and L2 influence the emotional resonance of words. Words in the L2 often lack strong emotional connotations, which are usually acquired during childhood (Altarriba, 2003; Harris et al., 2006). Consequently, bilinguals typically exhibit more pronounced automatic reactions to emotional vocabulary in their L1 than in their L2.

2.3 Emotional word processing in bilingual speakers

For bilingual speakers, language constitutes an internal variable that shapes emotional processing. At the behavioural level, emotion words are processed more accurately and rapidly in L1 than in L2 (e.g., Conrad et al., 2011; Schacht & Sommer, 2009). However, there is no consensus on whether negative or positive words exert facilitatory or inhibitory effects in L1 (e.g., Chen et al., 2015; Eilola et al., 2007; Estes & Verges, 2008; Kanske & Kotz, 2007; Kousta et al., 2009; Palazova et al., 2011; Pratto & John, 1991). Conversely, L2 processing is typically characterized by reduced emotional differentiation, often attributed to diminished emotional engagement. Consequently, neutral and emotional words tend to elicit comparable behavioural responses (e.g., Chen et al., 2015; Eilola et al., 2007; Segalowitz et al., 2008), although when differences emerge, they are often driven by positive words (e.g., Conrad et al., 2011; Ponari et al., 2017). Beyond behavioural measures, electrophysiological evidence supports these language-dependent differences, showing that while valence effects are present in both languages, their magnitude is modulated by the language context (e.g., Chen et al., 2015; Conrad et al., 2011; Jończyk, 2016; Jończyk et al., 2024; Vélez-Uribe & Rosselli, 2020).

Emotional language processing is often attenuated in L2, particularly in response to negatively valenced content (e.g., Tang et al., 2024; Wu & Thierry, 2012; Zhang et al., 2023). In a recent study, Tang and colleagues (2024) reported that negative words enhanced LPC amplitudes relative to neutral words in the L1, and elicited larger LPC activity than positive words, consistent with the well-established "*negativity bias*" (e.g., Baumeister et al., 2001; Ito et al., 1998). In contrast, L2 processing showed a different pattern. Tang et al. (2024) found that positive words evoked LPC amplitudes comparable to neutral words, but larger LPC amplitudes than those elicited by negative words. This pattern reflects a "*positivity offset*", in which positive stimuli in less emotionally grounded contexts evoke stronger processing (e.g., Zhang et al., 2014). Together, these results indicate stronger emotional engagement for negative words in L1, but relatively greater engagement for positive words in L2.

This shift from a "*negativity bias*" in L1 to a "*positivity offset*" in L2 may stem from differences in semantic-emotional integration. In L1, emotional meaning is deeply grounded in personal experiences and emotional memory, therefore the close relationship between the lexical semantics of words and their emotional connotations facilitate the processing of emotional meaning (Harris et al., 2003; Pavlenko, 2012). This is particularly evident for negative information, which is evolutionarily relevant for threat detection and adaptive responses, such as fleeing or freezing (e.g., Baumeister et al., 2001; Öhman, 2005).

By contrast, the L2 is often less embedded in emotional experiences, resulting in weaker semantic-emotional integration. Accessing emotional meaning may therefore require greater cognitive effort, particularly for negative words (Jończyk, 2016; Wu & Thierry, 2012). This reduced emotional grounding may contribute to the "*positivity offset*" in L2, as observed by Tang et al. (2024). Enhanced LPC activity in response to positive stimuli may also stem from a learning effect in L2 acquisition. For example, Ponari et al. (2017) reported that positive words are acquired earlier than negative words, which may facilitate their emotional processing.

However, findings across studies are not entirely consistent. Some studies reported larger LPC amplitudes for negative words in L2 than in L1, suggesting delayed re-evaluation of negative content at later processing stages (Jończyk et al., 2016). Jończyk et al. (2016) proposed that this pattern reflects a protective mechanism, whereby early suppression of negative stimuli leads to increased evaluation at later processing stages (see also Wu & Thierry, 2012). By contrast, emotional meaning in L1 is accessed more automatically, reducing the need for subsequent re-evaluation. Other studies also reported reduced or absent valence differences in L2, possibly reflecting increased cognitive demands associated with

integrating emotional meaning (Chen et al., 2015; Conrad et al., 2011).

Importantly, these observations have predominantly been made in the written modality, leaving open the question of whether similar effects occur during auditory word processing. To date, no research has been devoted to the role of emotional content in spoken language processing. As Opitz and Degner (2012) pointed out, research on emotional processing in L1 and L2 should extend to more natural stimulus materials, such as speech, to better capture real-world language use.

2.4 The influence of modality on emotional language processing

Speech unfolds over time, requiring continuous attention, as listeners cannot easily revisit previously presented segments. Monolingual research on the role of modality in non-emotional language processing has suggested that lexico-semantic mechanisms engage earlier with auditory than visual linguistic stimuli (Holcomb & Neville, 1990). This yields more robust effects of semantic expectancy on accuracy and response times, as well as earlier and larger electrophysiological responses (Holcomb et al., 1992).

Despite these insights, the role of modality in emotional language processing has received little attention. Spoken language conveys richer emotional information through additional non-verbal cues, such as prosody (e.g., Kotz & Paulmann, 2007). These cues facilitate early emotional differentiation and processing of stimuli, beginning as early as 200 ms after stimulus onset (e.g., Jakimik & Glenberg, 1990; Paulmann & Kotz, 2008a). Importantly, as this differentiation process occurs very early, it may operate independently of attentional processes for lexical emotional stimuli (Paulmann & Kotz, 2008a). Non-verbal emotional cues in speech are therefore processed differently than the emotional semantics of written words, suggesting that auditory and visual input may activate modality-specific emotional representations (Astésano et al., 2003; Paulmann & Kotz, 2008b; Pell, 2005).

Research in bilingual populations explored modality effects using psychophysiological measures such as pupillometry and skin conductance responses (SCRs; Caldwell-Harris & Ayçiçeği-Dinn, 2009; Harris et al., 2003; Harris, 2004; Jankowiak & Korpal, 2018; Yao et al., 2023). These studies suggest that emotionally salient words are more emotionally intense in participants' L1 when heard than read (Caldwell-Harris & Ayçiçeği-Dinn, 2009; Dewaele, 2004; Harris et al., 2003; Harris et al., 2006). In their study, Harris et al. (2003) examined the emotional engagement of Turkish (L1)-English (L2) bilingual speakers when exposed to taboo words and reprimands. SCRs revealed stronger emotional reactivity to reprimands when presented visually in L1 than in L2. Importantly, a modality effect emerged for taboo words in L1: auditory presentation elicited stronger SCRs than visual presentation, whereas no such effect was observed in L2. The auditory modality therefore yielded a larger emotional impact in L1 than in L2. The authors argued that speech is the primary means by which the L1 is acquired, whereas reading is learned later as a cognitive skill. As L1 acquisition develops alongside emotional regulation systems, auditory input is more closely linked to emotional arousal than visual input, eliciting more emotionally evocative responses than visual input (Bloom & Beckwith, 1989; Caldwell-Harris, 2014).

Harris (2004) extended this work to early and late Spanish (L1)-English (L2) bilinguals, examining whether the age of acquisition influences emotional engagement with taboo words, sexual terms, childhood reprimands and neutral words in visual and auditory modalities. Among early bilinguals, a modality effect was observed in both languages, with stronger SCRs for auditorily presented stimuli. The auditory effect only appeared to be a bit more nuanced. Similarly, Caldwell-Harris and Ayçiçeği-Dinn (2009) found reduced emotional reactivity to auditorily presented emotional stimuli in L2 relative to L1, indicating that the emotional enhancement associated with auditory input in the L1 may be attenuated in an L2.

A recent study by Yao and colleagues (2023) examined the emotional impact of L1 and L2 words presented auditorily using pupillometry. The stimuli included taboo words as well as negative and positive emotion words. The results revealed stronger emotional effects for taboo words in L1, with emotional responses attenuating when these words were presented in L2. In contrast, emotionality effects for emotion words were not significant. The authors argued that the differential emotional processing observed for taboo words is consistent with the well-established "*negativity bias"* (e.g., Baumeister et al., 2001). This pattern reflects a general reduction in emotional responses to aversive stimuli, even when they are presented auditorily.

Although these studies offer valuable insights, they do not reveal the temporal dynamics of emotional language processing in the brain. ERPs allow us to examine how emotional processing differs across languages over time given a specific emotional word. Yet, ERP research has not investigated whether emotional detachment in L2 extends to this modality. Further research is needed to understand how emotional words evoke neural responses when presented auditorily across languages (Sharif & Mahmood, 2023). Hence, the main aim of the current study was to examine whether emotional word processing differs between L1 and L2 in the auditory modality and whether this difference is reflected in ERP components associated with emotional processing in the written modality.

2.5 The current study

This study investigates whether language affects the processing of emotional information in the auditory modality. Specifically, the study investigates whether emotionally valenced spoken words (negative, neutral and positive) modulate emotional engagement during auditory language processing, and whether these effects differ between an L1, assumed to be emotionally closer, and an L2, which is typically considered emotionally more distant.

To address these questions, Dutch (L1) – English (L2) bilingual speakers participated in a valence judgement task. During the task, participants were presented with emotionally valenced target words (negative, neutral, or positive) in either their L1 or L2. After hearing each word, participants were required to indicate whether the emotional meaning of the stimulus corresponded to a negative, neutral, or positive valence.

It is hypothesised that emotional resonance will be modulated by both language and word valence. Regarding word valence, two primary results are predicted. First, emotional words (negative and positive) are expected to evoke distinct behavioural and neural responses compared to neutral words. Second, negative words are expected to evoke distinct responses compared to positive words. In L1, emotional words are hypothesised to enhance emotional engagement compared to neutral words. At the behavioural level, emotional words are expected to show higher accuracy and shorter response times (RTs) compared to neutral words (e.g., Chen et al., 2015; Kanske & Kotz, 2007; Kousta et al., 2009; Palazova et al., 2011; Schacht & Sommer, 2009). Additionally, higher accuracy and shorter RTs are anticipated for negative words than for positive words (Estes & Verges, 2008; Kauschke et al., 2019).

At the neural level, this should be reflected in larger LPC amplitudes for emotional words than for neutral words (Herbert et al., 2006). Negative and positive words require greater cognitive and attentional resources than neutral words, resulting in larger LPC amplitudes (e.g., Kanske & Kotz, 2007; Tang et al., 2024; Zhang et al., 2017; Zhang et al., 2023). In addition, negative words are hypothesised to evoke larger LPC amplitudes in comparison to positive words, consistent with the "*negativity bias*" reflecting enhanced attentional capture and stronger emotional impact (e.g., Chen et al., 2015; Kanske & Kotz, 2007; Tang et al., 2024).

In contrast, emotional resonance in L2 is expected to be reduced compared to the L1 (e.g., Caldwell-Harris & Ayçiçeği-Dinn, 2009; Harris et al., 2003). At the behavioural level, accuracy is expected to decrease and RTs to increase relative to L1 due to an increased cognitive effort (e.g., Chen et al., 2015; Segalowitz et al., 2008). Moreover, emotional words are not expected to elicit different behavioural responses compared to neutral words as a result of diminished emotional engagement (e.g., Chen et al., 2015; Eilola et al., 2007). However, positive words may be better recognised than negative words, given their early acquisition in L2, resulting in higher accuracy and shorter RTs (Conrad et al., 2011; Ponari et al., 2017).

At the neural level, the attenuated emotional engagement will be evident in smaller or non-significant modulations of the LPC in response to emotional compared to neutral words, and to negative compared to positive words (e.g., Chen et al., 2015; Conrad et al., 2011; Tang et al., 2024), attributable to the occurrence of emotional disengagement in L2 (Pavlenko, 2012).

3. Method

3.1. Participants

Forty-one Dutch-English speakers participated in the experiment; five participants were excluded from the analyses due to low quality of the recorded EEG signal or technical problems during response collection. The final sample consisted of 36 Dutch (L1) – English (L2) bilinguals. Seventeen participants were randomly assigned to the L1 condition (Dutch, 12 females and 5 males, M_{age} = 23.0 years, *SD* = 3.18) and nineteen to the L2 condition (English, 14 females and 5 males, M_{age} = 22.5 years, *SD* = 3.19). Participants in both conditions were aged between 18 and 25 years old and did not statistically differ in age ($t(33.57) = 0.45$, $p = .66$).

All participants were native speakers of Dutch and reported acquiring their L2 after the age of 7 (*SD* = 2.47) in an instructional learning environment. They were classified as highly proficient, late unbalanced Dutch-English bilinguals, based on LexTALE scores (Lemhöfer & Broersma, 2011) and self-ratings from the Language History Questionnaire 3.0 (LHQ, Li et al., 2019, see Table 1). Based on self-assessed Dutch and English proficiency, independent t-tests showed no differences between the L1 ($t(33.51) = 0.61$, $p = .55$) and L2 groups ($t(33.73) = 1.22$, $p = .23$). Thus, despite the between-subjects design, participants assigned in both conditions were comparable in language proficiency.

The participants reported no presence of any language, neurological, or psychiatric disorders, and had normal or corrected-to-normal vision. Moreover, they indicated that they were not taking any psychoactive drugs and were in a positive emotional state during the time of data collection. In addition, all participants identified as being right-handed (see Table 2).

Participation was voluntary and ethical approval for the experimental protocol was granted by the Ethics Assessment Committee Humanities of Radboud University (7/2024/2025). Participants received points for taking part.

Table 1. Participants' language background and proficiency (given in means (SDs)).

Feature	Dutch (L1)	English (L2)
Objective L2 Proficiency[1]	N/A	88.23 (10.68)
Subjective L2 Proficiency[2]	95.54 (6.30)	81.15 (12.57)
Dominance[2]	59.50 (6.19)	48.60 (9.68)
Immersion[2]	93.60 (1.64)	61.99 (10.60)
Years of use[2]	22.75 (3.15)	15.08 (4.20)
Age of L2 Acquisition[2]	N/A	7.67 (2.47)
Frequency of expression emotion[2]		
Positive	5.83 (0.85)	3.39 (1.29)
Negative	5.19 (1.35)	3.39 (1.23)

[1] Based on the LexTALE test (given as percentages; Lemhöfer & Broersma, 2011): the CEFR levels B1 (0-59%), B2 (60-80%), C1 and C2 (80-100%);
[2] Based on the Language History Questionnaire 3.0 (LHQ; Li et al., 2020): proficiency, dominance and immersion scores are given as percentages based on listening, reading, speaking and writing skills (1 – very low proficiency, 7 – very high proficiency); age of acquisition and years of use (given in years), and frequency of expressing emotions (1- never, 7- always).

Table 2. Bio-demographic data of the participants.

Characteristics	Mean [95% CI]
Positive affect[1]	33.83 [31.96, 35.71]
Negative affect[1]	22.81 [20.54, 25.07]
Handedness[2]	88.06 [82.12, 93.99]

[1] Based on the Positive and Negative Affective Schedule (PANAS; Watson et al., 1988; adapted into Dutch by Peeters et al., 1996[1]);
[2] Based on the Edinburgh Handedness Inventory (Oldfield, 1971): left-handedness (-100–-28), ambidexterity (-29–48), and right-handedness (48–100).

3.2. Materials

3.2.1. Stimuli

The linguistic material comprised 288 translation equivalents between Dutch (L1) and English (L2), with 144 emotional words for each language. These words were categorized by word valence into three distinct categories: negative, neutral, and positive. Each language contained an equal number of nouns (i.e., 48) per valence category (see Table 3 for the lexicosemantic characteristics of the words and Appendix A for the complete list of stimuli).

Words were classified into negative, neutral, and positive categories based on the valence rating from the Dutch (Speed & Brysbaert, 2023) and English (Warriner et al., 2013) valence databases. Words with valence ratings below 2.5 were categorized as negative, those between 2.5 and 3.5 as neutral, and those above 3.5 as positive. A comparison between Dutch and English revealed a significant difference for negative words ($t(94) = -9.55$, $p < .001$, Cohen's $d = 1.95$), indicating that negative words in Dutch were rated as more negative than their English counterparts ($M_{difference} = -0.38$, 95% CI [-0.46, -0.30]). Additionally, a significant difference was found for neutral words ($t(94) = -3.57$, $p < .001$, Cohen's $d = 0.73$), suggesting that neutral words in Dutch were rated as more neutral compared to their English counterparts ($M_{difference} = -0.11$, 95% CI [-0.16, -0.05]). Conversely, no significant difference was found between Dutch and English for positive words ($t(94) = 0.21$, $p = .84$).

A subsequent comparison of the word valence levels (negative, neutral and positive) demonstrated a significant effect for Dutch ($F(2, 141) = 3023$, $p < .001$, $\eta^2 = .98$). Post-Tukey HSD tests revealed that positive words were more positive than neutral ($M_{difference} = 1.10$, 95% CI [1.01, 1.19], $p < .001$) and negative words ($M_{difference} = 2.89$, 95% CI [2.80, 2.98], $p < .001$). Additionally, negative words were found to be more negative than neutral words ($M_{difference} = -1.79$, 95% CI [-1.88, -1.70], $p < .001$). A similar pattern emerged in English, demonstrating a statistically significant difference between the three word valences ($F(2, 141) = 1644$, $p < .001$, $\eta^2 = .96$). Post-hoc Tukey HSD analysis demonstrated that positive words were rated as more positive than neutral ($M_{difference} = 0.98$, 95% CI [0.88, 1.09], $p < .001$) and negative words ($M_{difference} = 2.50$, 95% CI [2.40, 2.61], $p < .001$). Moreover, negative words were rated as more negative than neutral words ($M_{difference} = -1.52$, 95% CI [-1.62, -1.42], $p < .001$).

Furthermore, arousal ratings were examined for Dutch and English across the three word valence categories to assess whether arousal was comparable across languages. Results revealed a significant difference in arousal ratings for the negative words ($t(94) = 3.61$, $p < .001$, Cohen's $d = 0.74$), indicating that negative words in Dutch were rated as more arousing compared to their English counterparts ($M_{difference} = 0.34$, 95% CI [0.15, 0.53]). A similar pattern emerged for neutral words ($t(94) = 6.31$, $p < .001$, Cohen's $d = 1.29$), with Dutch neutral words rated as more arousing compared to their English counterparts ($M_{difference} = 0.40$,

[1] The Dutch version was validated in 1996; consequently, the Dutch translations were reviewed and updated with more contemporary translations for certain emotional states. Two native speakers of Dutch verified the validity of these new translations, as well as the previously validated translations of Peeters et al. (1996).

95% CI [0.28, 0.53]). Conversely, no significant difference in arousal ratings was found between Dutch and English positive words ($t(94) = -0.73$, $p = .47$).

Moreover, a comparison of the arousal ratings between negative, neutral and positive words revealed a significant difference in Dutch ($F(2, 141) = 65$, $p < .001$, $\eta^2 = .48$). Post hoc Tukey HSD tests revealed that negative words were more arousing than both neutral ($M_{difference} = 0.98$, 95% CI [0.75, 1.21], $p < .001$) and positive words ($M_{difference} = 0.89$, 95% CI [0.67, 1.12], $p < .001$). Additionally, no differences in arousal ratings were found between neutral and positive words ($M_{difference} = 0.09$, 95% CI [-0.14, 0.31], $p = .62$).

A similar pattern emerged in English, with a significant effect of valence ($F(2, 141) = 75$, $p < .001$, $\eta^2 = .52$). Post hoc Tukey HSD tests demonstrated that negative words were more arousing than both neutral ($M_{difference} = 1.04$, 95% CI [0.84, 1.24], $p < .001$) and positive words ($M_{difference} = 0.47$, 95% CI [0.27, 0.67], $p < .001$). Moreover, positive words were rated as more arousing than neutral words ($M_{difference} = 0.57$, 95% CI [0.37, 0.77], $p < .001$).

All translation equivalent pairs were further matched for concreteness to ensure a balanced representation of abstract and concrete words across the three word valence categories. The classification of concreteness was based on the Dutch (Brysbaert et al., 2014) and English (Brysbaert et al., 2013) concreteness databases. Words with ratings below 3 were classified as abstract, while those above 3 were categorised as concrete. Differences in concreteness between abstract and concrete words were significant in both Dutch ($M_{abstract} = 2.08$, 95% CI [1.98. 2.17], $M_{concrete} = 4.08$, 95% CI [3.92, 4.24]; $t(142) = -21.51$, $p < .001$, Cohen's $d = 3.58$) and English ($M_{abstract} = 2.34$, 95% CI [2.23, 2.45], $M_{concrete} = 4.31$, 95% CI [4.18, 4.45]; $t(142) = -22.64$, $p < .001$, Cohen's $d = 3.77$). Additionally, a difference between Dutch and English was found regarding abstract ($t(142) = -3.56$, $p < .001$, Cohen's $d = 0.59$), as well as concrete words ($t(142) = -2.28$, $p < .05$, Cohen's $d = 0.38$). Words were rated as more abstract in Dutch ($M = 2.08$, 95% CI [1.98, 2.17]) compared to English ($M = 2.34$, 95% CI [2.23, 2.45]), whereas words were rated as less concrete in Dutch ($M = 4.08$, 95% CI [3.92, 4.24]) compared to English ($M = 4.31$, 95% CI [4.18, 4.45]).

Words forming translation-equivalent pairs were systematically matched for frequency, using the Dutch (SUBLTEX-NL; Keuleers et al., 2010) and English (SUBTLEX-EN; Van Heuven et al., 2013) frequency databases. Analyses revealed no significant differences in the relative frequency between Dutch and English words across valence categories: negative ($t(94) = -0.24$, $p = .81$), neutral ($t(94) = -1.51$, $p = .13$), and positive words ($t(94) = -1.30$, $p = .20$). Once matched on word valence, concreteness, and frequency, words were included in the final stimuli set. Taboo and swear words, as well as interlingual homographs, homonyms, and identical cognates across the two languages, were excluded.

3.2.2 Recording and preprocessing audio files

The auditory stimuli were recorded in a sound-attenuated booth at the Centre for Language Studies, Radboud University, Nijmegen. Recordings were made using Audacity© with mono tracks, a sampling rate of 44,100 Hz, and 16-bit resolution. A female native speaker of Dutch articulated the words in a monotonous tone at a normal speech rate. The speaker acquired English as an L2 after the age of ten, predominantly in an instructional environment. Her English proficiency across the domains of listening, reading, speaking and writing, was evaluated as native-like on a 5-point Likert scale (1 = no knowledge, 2 = beginner, 3 = average, 4 = advanced, 5 = native-like).

Additionally, the sound files were standardized using the speech analysis package Praat (Boersma, 2001). A manual analysis of each file was conducted, with attention to silence preceding the acoustic onset and to vowel-initial words. Firstly, excess silence was removed to ensure each word began at its acoustic onset, determined by the zero-crossing point of the

amplitude. Given that silence was always cut off at a zero-crossing point, some plosive-initial words may retain up to 0.1 seconds of silence at onset. Secondly, for vowel-initial words any glottal stop or aspiration preceding the vowel was retained. This approach preserved naturalness, as glottal stops commonly occur at the start of the vowel-initial words when spoken in isolation, particularly in Dutch (Jongenburger & Van Heuven, 1991). When these glottal stops were removed, the words sounded slightly abrupt and not natural. All audio files were standardized at 0.5 Pascal and normalized to 65dB.

Table 3. Psycholinguistic characteristics of the target words for Dutch and English are presented in means accompanied by 95% confidence intervals.

	Dutch			English		
	Negative	Neutral	Positive	Negative	Neutral	Positive
Arousal[1]	3.78 [3.63, 3.93]	2.80 [2.72, 2.89]	2.89 [2.73, 3.05]	3.44 [3.32, 3.56]	2.40 [2.30, 2.50]	2.97 [2.83, 3.11]
Valence[1]	1.26 [1.23, 1.29]	3.06 [3.02, 3.09]	4.16 [4.08, 4.24]	1.64 [1.57, 1.72]	3.16 [3.12, 3.21]	4.15 [4.08, 4.21]
Concreteness[2]	2.87 [2.65, 3.09]	3.25 [2.85, 3.66]	3.11 [2.76, 3.45]	3.11 [2.86, 3.36]	3.53 [3.15, 3.90]	3.35 [3.02, 3.67]
Frequency[3]	3.74 [3.55, 3.94]	4.15 [4.01, 4.29]	4.84 [4.72, 4.96]	3.77 [3.61, 3.93]	4.32 [4.14, 4.50]	4.95 [4.84, 5.06]
Letters[4]	8.48 [7.85, 9.11]	7.06 [6.35, 7.78]	6.21 [5.50, 6.92]	7.60 [7.01, 8.20]	6.77 [6.18, 7.36]	5.98 [5.36, 6.60]
Syllables[5]	2.58 [2.37, 2.80]	2.17 [1.91, 2.42]	1.85 [1.60, 2.11]	2.58 [2.30, 2.86]	2.21 [1.96, 2.45]	1.77 [1.54, 2.00]

[1]Arousal and Valence: 1 (negative/unarousing) – 5 (positive/arousing) scale: Speed & Brysbaert (2023) for Dutch and Warriner et al. (2013; the original 1-9 scale transformed to the 1-5 scale) for English;
[2] Concreteness: 1 (abstract) – 5(concrete) scale: Brysbaert et al. (2014) for Dutch and Brysbaert et al. (2013) for English;
[3] Frequency is based on the Zipf-scale: 1 (low) – 7 (high): SUBTLEX-NL (Keuleers et al., 2010) and SUBTLEX-EN (Van Heuven et al., 2014);
[4] Range = 3-13 letters;
[5] Range = 1-5 syllables.

3.3 Procedure

Participants were recruited and pre-screened through the Radboud Research Participation System (SONA). Recruitment involved a demographic questionnaire assessing age, L1, L2, and medical history. Only participants meeting the specified criteria were invited to the laboratory.

The experiment was conducted at the Centre for Language Studies, Radboud University, Nijmegen. After providing written informed consent, participants were seated in a dimly lit and soundproof booth. They first completed the English version of the LexTALE questionnaire (Lemhöfer & Broersma, 2011) and the Dutch version of the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988, adapted by Peeters et al., 1996). The PANAS assessed the emotional state of the participants at the time of data collection, which was important given the crucial role of mood in the automaticity of bilingual language processing (e.g., Naranowicz et al., 2022; Naranowicz & Jankowiak, 2024). Following the completion of the aforementioned questionnaires, the EEG cap was prepared while participants completed the Dutch versions of the Language History Questionnaire 3.0 (LHQ 3.0; Li et al., 2019), and the Edinburgh Handedness Inventory (Oldfield, 1971).

The stimuli were presented using the OpenSesame software (version 4.1.1., Mathôt et al., 2012). Participants were randomly assigned to either the Dutch (L1) or English (L2) version of the experiment. Irrespective of the language, the instructions were administered in Dutch. The experiment comprised 144 trials presented in a random order. After 72 trials, participants were required to take a break to reduce potential fatigue effects. Prior to the experiment, participants completed a practice block of six practice trials to familiarize themselves with the task. These practice trials were excluded from the experimental analyses.

Upon hearing an emotional word via the Etymotic ER-1 insert Earphones (Etymotic Research, Inc., IL, USA) connected to the BrainVision SimTrak (Brain Products GmbH, Germany), participants were tasked with performing a valence judgement. They had to indicate whether the word they heard was negative, neutral or positive by pressing the ‘A’, ‘B’ or ‘C’ buttons on the button box, referred to as the ‘LEFT’, ‘MIDDLE’ and ‘RIGHT’ button, respectively. The assignment of the ‘LEFT’ and ‘RIGHT’ buttons, which could be either negative or positive, was counterbalanced among participants, whereas the ‘MIDDLE’ button was consistently assigned to neutral valence.

Each trial began with a fixation cross (500 ms), followed by a blank screen (500 ms). A fixation dot then appeared to indicate the audio onset, which played immediately upon the dot’s appearance. From the onset of the auditory stimulus, participants could indicate their valence judgment. Following the offset of the auditory stimulus, a 2000 ms response window remained during which participants could still respond. The fixation dot remained visible both during the audio presentation and throughout the post-audio response window, indicating that the participants were still able to make a decision in the post-audio period. Upon pressing a button or when the 2000 ms time window elapsed, the trial was ended and the experiment advanced to a blank screen of the 1500 ms inter-trial interval.

Following the EEG recording session, participants completed a brief questionnaire examining their emotional and linguistic tendencies to determine their preferred language and its use in expressing various emotions (see LHQ 3.0; Li et al., 2019). The questionnaire was administered after the main experiment, to avoid biasing participants with regard to the interplay of language and emotions, which were the variables of interest. The total duration of the experiment was about 1.5 hours.

3.4 Electrophysiological recording and preprocessing

Continuous EEG signals were recorded at 500Hz from 60 Ag/AgCl scalp electrodes (i.e., AF7, AF3, AFz, AF4, AF8, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FT7, FC5, FC3, FC1, FCz, FC2, FC4, FC6, FT8, T7, C5, C3, C1, Cz, C2, C4, C6, T8, TP9, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, TP10, P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, Poz, PO4, PO8, O1, Oz, and O2) arranged according to the International 10-20 system (Jasper, 1958). Four electrodes were obtained from the cap to identify eye movement artefacts. The horizontal and vertical electro-oculogram (EOG) was measured from electrodes placed at the outer canthi of both eyes (FT9 and FT10), and above and below the left eye (FP1 and FP2). The ground electrode was positioned on the Fpz electrode on the forehead. Electrodes were referenced online to the Cz electrode. All signals were amplified using an actiCHamp amplifier (Brain Products GmbH, Germany) and recorded using BrainVision Recorder software (Brain Products, Gilching, Germany). The impedance (offset) level for each electrode was kept at ± 15 μV.

BrainVision Analyzer 2.3 software (Brain Products, Germany) was used to analyse the EEG data offline. Continuous EEG data were down-sampled to 256 Hz and referenced to the global average reference of all scalp electrodes (Luck, 2014; Nunez & Srinivasan, 2006) with Cz being reused as EEG channel. The data was corrected for ocular artefacts via Independent Component Analysis (ICA). On average, 5.64 independent components (*SD* = 0.48, range = 4-7) were rejected per participant during ICA. The signal was then filtered offline applying a Butterworth zero phase filter with a high-pass filter set at 0.1 Hz and a low-pass filter set at 20 Hz (slope 24 dB/octave). Additionally, the signal was segmented into epochs ranging from 200 ms before target onset to 1500 ms afterwards, followed by baseline-correction between -200 and 0 ms in reference to pre-stimulus activity. For artifact rejection, the following thresholds were set: voltage differences higher than 100 μV, maximal allowed voltage step at 50 μV, and lowest allowed activity at 5 μV (i.e., rejecting trials with flatlining events).

Overall, 99.73% of the trials were included in the analysis (*SD* = 0.58, range = 97.92%-100%), with the average number of retained epochs per condition above 47 for all the conditions (out of 48 trials per condition; L1 positive, *M* = 47.88, *SD* = 0.33, range = 47–48; L1 negative, *M* = 47.82, *SD* = 0.53, range = 46–48; L1 neutral, *M* = 47.76, *SD* = 0.56, range = 46–48; L2 positive, *M* = 47.89, *SD* = 0.32, range = 47–48; L2 negative, *M* = 47.95, *SD* = 0.23, range = 47–48; L2 neutral, *M* = 47.89, *SD* = 0.32, range = 47–48). All participants had more than 95% of trials per individual condition, therefore none were excluded.

3.5 Design and data-analysis

The present study employed a 2 (Language: Dutch (L1) versus English (L2)) by 3 (Word Valence: negative versus neutral versus positive) mixed-design, with Language as between-subjects and Word Valence as within-subjects independent variable. The behavioural analyses included response accuracy and response times (RTs). Response accuracy was defined as the extent to which participants' valence classifications corresponded to the normative ratings provided by the databases. Further, RTs for incorrect responses and those shorter than 150 ms were discarded from the analysis (13.8%) to ensure the integrity of the data.

Electrophysiological analyses included one event-related potential (ERP) component previously reported to be modulated by emotional language in L1 and L2: the LPC (e.g., Citron, 2012; Jończyk et al., 2024; Tang et al., 2024). ERP analyses were performed within the pre-defined time window between 500-800 ms over a centroparietal region (C1, Cz, C2, CP1, CPz, CP2, P1, Pz, and P2 electrodes). Notably, as there is little to no evidence of this component in the auditory modality, the present study focuses exclusively on the LPC to examine its appearance in an auditory context, despite evidence that the EPN is also sensitive

to emotion in both the auditory and written modalities (e.g., Frühholz et al., 2011; Jaspers-Fayer et al., 2012; Kissler & Herbert, 2012; Mittermeier et al., 2010; Palazova et al., 2011). This focus is further justified because the LPC is modulated by an explicit assessment of word valence, the task given in the present study (e.g., Carretié et al., 2008a; Citron, 2012; Frühholz et al., 2011; Hajcak et al., 2009; Hinojosa et al., 2010; Kissler et al., 2007).

All statistical analyses were performed in R (R Core Team, 2024). Statistical analyses of response accuracy were conducted with a generalized linear-mixed model including a binominal distribution (GLMM; Bolker, 2008; Jaeger, 2008), while the RT and ERP data (i.e., mean amplitudes for single trials in the LPC time window) were conducted by means of linear mixed-effects models (LMMs; Baayen et al., 2008; Barr, 2013), using the *lme4* package (Bates et al., 2015). For each model, a maximal (G)LMM model was first constructed with a full random-effect structure, including item- and subject-related variances for intercepts and by-participant and by-item random slopes for fixed-effects (Barr, 2013). If a maximal model failed to converge, the recommendations from Bates et al. (2018, see also Matuschek et al., 2017) were followed to create the most parsimonious model. None of the models showed collinearity (Variance Inflection Factor < 1.5).

Word Valence was encoded using Helmert to represent two orthogonal comparisons. The first contrast compared neutral words (coded as -2/3) with the two emotion words (negative and positive, each coded as 1/3). The second contrast directly compared the two emotional conditions (negative coded as 1/2 and positive coded as -1/2). Language was sum-coded (Dutch as -1/2 and English as 1/2). Fixed-effect estimates and associated significance levels (*p*-values) were obtained using Satterthwaite's approximation as implemented in the *lmerTest* package (Kuznetsova et al., 2017). Pairwise comparisons were conducted using the *emmeans* package (version 2.0.2; Lenth & Piaskowski, 2026) and adjusted for multiple testing using the Bonferroni correction. The final parsimonious model structure for each analysis is reported below.

(1) $GLMM_{accuracy}$: glmer(ACC ~ word valence * language + (1 | participant) + (1 | item), data = data_accuracy, family = binomial (link = "logit"))
(2) LMM_{RT}: lmer(RT ~ word valence * language + (1 | participant) + (1| item), data = data_RT)
(3) LMM_{LPC}: lmer(mean_amp ~ word valence * language + (1 | participant) + (1 | item), data=data_LPC)

4. Results

4.1 Behavioural results

Response accuracy. Figure 1 presents the mean response accuracy, reported as percentages of correct responses, by Language and Word Valence. Accuracy for negative words was higher in Dutch (L1, $M = 98.1\%$, $SD = 13.6$) than in English (L2, $M = 93.0\%$, $SD = 25.5$). In Dutch, negative words were identified with higher accuracy than both neutral and positive words, with neutral words ($M = 86.2\%$, $SD = 34.5$) recognized more accurately than positive words ($M = 76.1\%$, $SD = 42.7$). In English, negative words were also identified with higher accuracy than neutral and positive words, except that positive words ($M = 84.1\%$, $SD = 36.6$) were recognized with higher accuracy than neutral words ($M = 79.8\%$, $SD = 40.1$). The difference in accuracy between negative and positive words was larger in Dutch than in English.

The model results for the dependent variable response accuracy are given in the Appendix (Table B1). The analysis showed a main effect of Word Valence for Contrast 1 ($b_{\text{NEUTRALvsEMOTION}} = -1.00$, $SE = 0.19$, $z = -5.31$, $p < .001$, odds ratio = 0.37), indicating that accuracy was higher for emotional words than for neutral words. In addition, the analysis demonstrated an effect for Contrast 2 ($b_{\text{NEGATIVELvsPOSITIVE}} = 2.23$, $SE = 0.25$, $z = 8.78$, $p < .001$, odds ratio = 9.26), which shows that negative words were recognized more accurately than positive words. Moreover, no significant main effect of Language was shown ($b = -0.44$, $SE = 0.25$, $z = -1.71$, $p > .05$).

Furthermore, the results showed a significant interaction between Language and Word Valence for Contrast 2, suggesting that the difference in accuracy between positive and negative words is language-dependent ($b = -2.25$, $SE = 0.50$, $z = -4.51$, $p < .001$, odds ratio = 0.11). Pairwise comparisons indicated higher accuracy scores in Dutch for negative words than for positive words ($b = 3.35$, $SE = 0.40$, $z = 8.37$, $p < .001$, odds ratio = 28.46). A similar pattern was observed for English, with higher accuracy rates for negative compared to positive words ($b = 1.10$, $SE = 0.30$, $z = 3.63$, $p < .001$, odds ratio = 3.01), although the magnitude of this difference was smaller than in Dutch. With regard to negative words, accuracy was higher in Dutch than in English ($b = 1.51$, $SE = 0.45$, $z = 3.37$, $p < .001$, odds ratio = 4.55). Finally, the interaction between Language and Word Valence for Contrast 1 was not significant ($b = -0.13$, $SE = 0.37$, $z = -0.37$, $p > .05$).

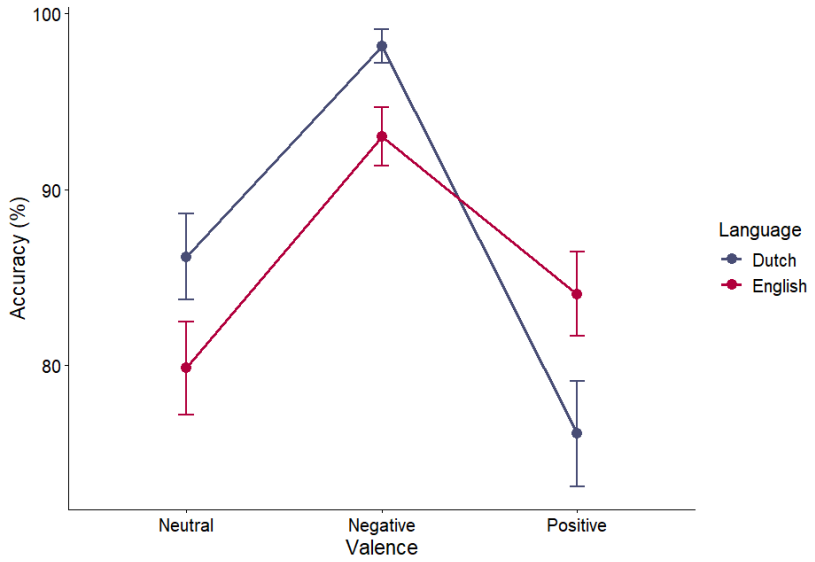


Figure 1. Mean accuracy rates (%) for neutral, negative and positive words in Dutch (L1) and English (L2) with their 95% confidence intervals.

Response times. Figure 2 shows the mean RTs in milliseconds as a function of Language and Word Valence. It demonstrates that, in Dutch (L1), responses were fastest for negative words (M = 1154 ms, SD = 363), followed by positive words (M = 1245 ms, SD = 374). In English (L2), participants responded slightly faster to positive words (M = 1150 ms, SD = 329) than to negative words (M = 1161 ms, SD = 317). Neutral words elicited the longest RTs in both Dutch (M = 1361 ms, SD = 366) and English (M = 1401 ms, SD = 356).

Appendix Table B2 presents the model results for RTs as dependent variable. The analysis indicated a main effect for Word Valence for Contrast 1 ($b_{\text{NEUTRALvsEMOTION}}$ = 203.82, SE = 16.62, t = 12.26, p < .001), demonstrating shorter RTs for emotional compared to neutral words. An effect was also observed for Contrast 2 of Word Valence ($b_{\text{NEGATIVEvsPOSITIVE}}$ = -49.14, SE = 19.08, t = -2.58, p < .05), revealing faster responses for negative compared to positive words. However, no effect of Language was found (b = -27.98, SE = 62.88, t = -0.45, p > .05)

Furthermore, a significant interaction between Language and Word Valence for Contrast 2 was found (b = 124.10, SE = 38.16, t = 3.25, p < .01). Pairwise comparisons demonstrated, for Dutch, shorter RTs for negative than for positive words (b = -111.20, SE = 27.30, z = -4.07, p < .001). In English, the difference between negative and positive words showed no significant effect (b = 12.90, SE = 26.60, z = 0.49, p > .05). Finally, the interaction between Language and Word Valence for Contrast 1 demonstrated no significant effect (b = 58.99, SE = 33.24, t = 1.77, p > .05).

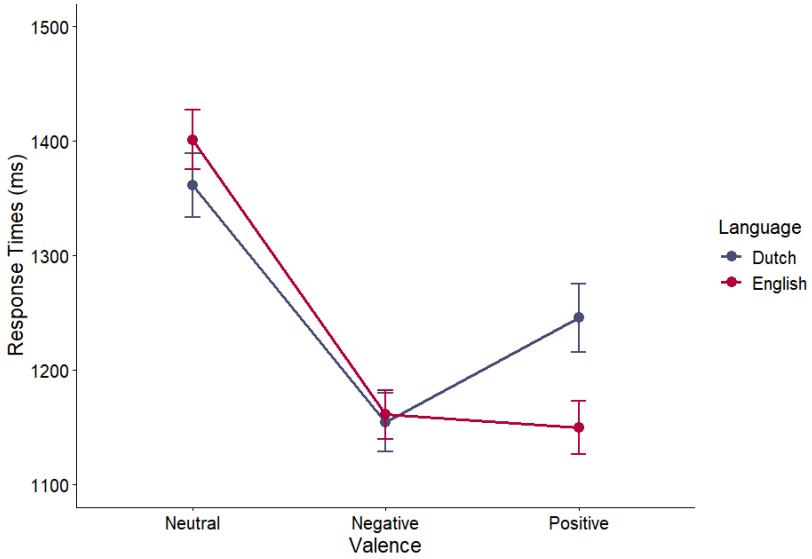


Figure 2. Mean RTs (ms) for neutral, negative and positive words in Dutch (L1) and English (L2) with their 95% confidence intervals.

4.2 Electrophysiological results

Late Positive Complex (LPC; 500-800ms). Figure 3 presents the grand-average LPC amplitudes for Word Valence (neutral, negative and positive words) as a function of Language (Dutch (L1) and English (L2)), alongside topographic maps depicting the differences in LPC amplitude for Contrasts 1 and 2 of Word Valence for each Language. In Dutch, emotional words elicited larger LPC amplitudes compared to neutral words (M = -0.87 μV, SD = 7.90), with negative words (M = 0.25 μV, SD = 8.86) yielding a greater LPC increase than positive words (M = -0.49 μV, SD = 8.41). In English, a similar pattern was observed; however, the differences between neutral (M = -1.52 μV, SD = 7.34), negative (M = -0.91 μV, SD = 6.75) and positive words (M = -1.21 μV, SD = 7.15) were reduced.

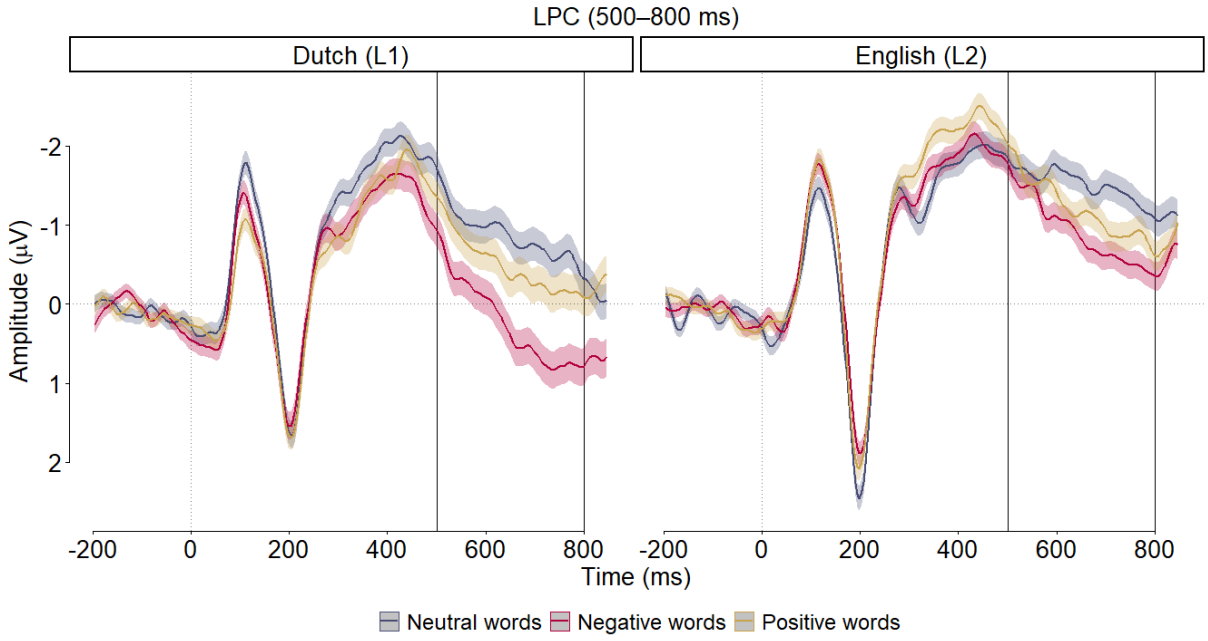
Appendix Table B3 presents the results of the linear mixed-effects model for the LPC time window. The analysis revealed a main effect of Word Valence for both Contrast 1 and Contrast 2. The effect of Contrast 1 demonstrated a larger LPC amplitude for emotional (negative and positive) compared to neutral words ($b_{\text{NEUTRALvsEMOTIONAL}}$ = -0.61, SE = 0.19, t = -3.17, p < .01). In addition, the effect for Contrast 2 revealed a larger LPC amplitude for negative words than positive words ($b_{\text{NEGATIVEvsPOSITIVE}}$ = 0.52, SE = 0.22, t = 2.35, p < .05). There was no significant main effect of Language (b = -0.84, SE = 0.61, t = -1.37, p > .05).

The analysis revealed an interaction between Language and Word Valence for Contrast 1, indicating that the processing of neutral versus emotional stimuli is language-dependent (b = 0.29, SE = 0.15, t = 1.97, p < .05). In Dutch, LPC amplitudes were significantly larger for emotional compared to neutral words (b = -0.50, SE = 0.14, z = -3.64, p < .001). Similarly, in English, LPC amplitudes were significantly larger for emotional than neutral words (b = -0.31, SE = 0.14, z = -2.27, p < .05), although the effect was reduced compared to Dutch.

Additionally, the extent to which negative or positive words differed from neutral ones was explored across languages. In Dutch, LPC amplitudes were significantly larger for negative than neutral words (b = -1.12, SE = 0.24, z = -4.69, p < .001), whereas no significant difference was observed between positive and neutral words (b = -0.38, SE = 0.24, z = -1.61, p > .05). A similar pattern was observed in English: LPC amplitudes were larger for negative than for neutral words (b = -0.61, SE = 0.24, z = -2.61, p < .05), while positive and neutral words did not differ significantly (b = -0.31, SE = 0.24, z = -1.32, p > .05).

The interaction effect between Language and Word Valence for Contrast 2 was also found to be significant (b = -0.43, SE = .017, t = -2.54, p < .05). In Dutch, LPC amplitudes were increased for negative words compared to positive words (b = 0.74, SE = 0.24, z = 3.09, p < .01). In English, however, no effects between negative and positive words were found (b = 0.30, SE = 0.24, z = 1.29, p > .05).

A



B

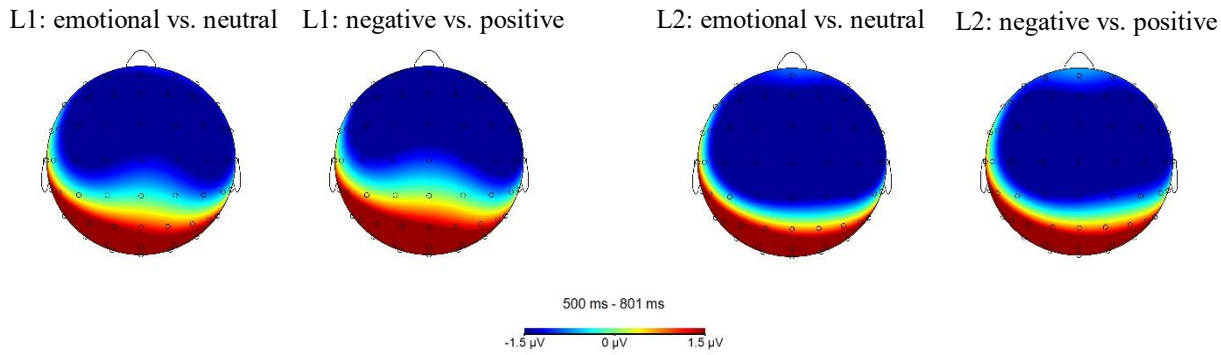


Figure 3. (A) Grand average LPC waveforms for neutral, negative and positive words for Dutch (L1) and English (L2) in the 500-800ms time window. (B) Topographic maps depicting differences in LPC amplitude between emotional (both positive and negative) and neutral words (contrast 1), and between negative and positive words (contrast 2), for each language in the 500-800ms time window.

5. General Discussion

The present ERP study aimed to investigate whether emotional engagement is attenuated in an L2 compared to the L1 during speech processing, at both behavioural and neural levels. More specifically, the influence of language (L1: Dutch versus L2: English) and valence (negative, neutral, or positive) on emotional word processing in the auditory modality was examined. While previous ERP research has focused exclusively on the written modality (e.g., Chen et al., 2015; Tang et al., 2024), little is known about how emotional words are processed when heard. Using a valence judgement task, it was investigated whether enhanced emotional responses to emotional words could be elicited in listeners when they heard negative (e.g., *war*), neutral (e.g., *door*), or positive (e.g., *love*) words in their L1 or L2. This paradigm directly compared how emotional meaning is processed across languages in the auditory modality, particularly by assessing response accuracy and response times and through the modulation of the LPC, an ERP component.

5.1 Emotional responses in L1

It was hypothesised that emotional words in L1 would elicit stronger behavioural and neural responses than neutral words (hypothesis 1), and that negative words would elicit stronger responses relative to positive words (hypothesis 2). The findings, however, revealed this pattern for neural responses, but not for behavioural responses, indicating a dissociation between the two in emotional processing in L1.

At the behavioural level, emotional words did not elicit a general behavioural advantage in terms of more accurate or faster responses than neutral words. Consequently, this result does not support the first hypothesis, which predicted behavioural differences between emotional and neutral words in L1. Nonetheless, participants responded more accurately and rapidly to Dutch negative words than to positive words. This provides support for the second hypothesis regarding differential behavioural responses to negative and positive stimuli. This pattern suggests that negative information exerted a stronger influence on response selection, even in the absence of a general emotional advantage over neutral words.

Behavioural responses to negative words can manifest in various forms, ranging from an absence of physical movement (i.e. freezing) to heightened motor activity (i.e. the fight-or-flight response; e.g., Carretié et al., 2008b; Damasio, 2001). Faster and more accurate responses to negative words reflect early attentional prioritisation of negative information (Baumeister et al., 2001). From an evolutionary perspective, this pattern aligns with adaptive accounts of emotional processing, which propose that individuals are tuned to detect potentially threatening stimuli rapidly. However, this finding contradicts research showing that negative words cause slower responses due to greater cognitive disruption (e.g., Estes & Adelman, 2008; Pratto & John, 1991; Wentura et al., 2000). In the present study, negative words enhance engagement and facilitate response selection. Rather than eliciting a literal fight-or-flight response, negative words prepared the motor system to respond more quickly to negative words, resulting in faster responses consistent with an avoidance-oriented behavioural tendency (e.g., Estes & Adelman, 2008; Kauschke et al., 2019; Pratto & John, 1991). While this avoidance-oriented facilitation has been previously demonstrated in written word processing, this study provides novel evidence that this effect also extends to the auditory modality.

At the neural level, clear evidence for enhanced emotional processing in L1 was observed. Emotional words elicited larger LPC amplitudes than neutral words over centroparietal brain regions, corroborating the first hypothesis at the neural level. Moreover, Dutch negative words evoked significantly larger LPC amplitudes than positive words, consistent with the second hypothesis and indicating stronger emotional engagement with

negative words. This suggests that the emotional-neutral LPC differences are primarily driven by negative words. This interpretation is further supported by the observation of comparable LPC responses to positive and neutral words, as evidenced by the exploratory findings related to the first hypothesis.

Enhanced LPC amplitudes are typically interpreted as reflecting sustained attention and deeper evaluative processing of emotional stimuli (e.g., Hajcak et al., 2009; Ito et al., 1998; Lang et al., 1997; Naumann et al., 1992). The enhanced LPC response to negative words in L1, therefore suggests prolonged allocation of attentional and motivational resources to negative information. These findings align with previous ERP studies reporting enhanced LPC responses for emotional, in particular negative words, in L1 (e.g., Kanske & Kotz, 2007; Tang et al., 2024; Zhang et al., 2017), and supports the notion that negative and positive evaluations rely on distinct motivational systems (e.g., Bradley, 2000; Chen & Bargh, 1999; Ito et al., 1998; Lang et al., 2000). Although positive words are emotionally relevant, they do not convey the same urgency or motivational significance as negative words.

The prioritisation of negative words in L1 aligns with an evolutionary perspective, according to which negative stimuli are time-sensitive and receive preferential behavioural and neural processing (e.g., Carretié et al., 2008b; Ito et al., 1998; Pratto & John, 1991). This pattern can be explained within the framework of the "*negativity bias*", whereby negative information is processed more deeply than positive information (e.g., Delaney-Busch et al., 2016; Estes & Adelman, 2008; Kanske & Kotz, 2010; Tang et al., 2024). Because L1 emotional concepts are strongly grounded through early acquisition in emotionally rich experiences, negative words may have more robust links to emotional responses and motivational systems (e.g., Barrett et al., 2007; Bloom & Beckwith, 1989; LaBar & Phelps, 1998). This notion is therefore not limited to written word processing, as shown in previous work, but also extends to the auditory modality, as demonstrated by the present findings.

In summary, emotional word processing in L1 revealed robust neural sensitivity to emotional content, particularly negative valence, alongside selective behavioural prioritisation of negative words. Negative words appear to hold a privileged emotional status in L1, reflecting strong emotional engagement than positive words. Although the notion of a "*negativity bias*" is not novel, the present study extends this idea to auditory emotional processing, demonstrating that this effect also emerges when bilinguals *listen* to emotional words in their L1.

5.2 Emotional responses in L2

The present study further hypothesised that emotional engagement would be reduced in the L2 relative to the L1 (hypothesis 3). This would be reflected in attenuated behavioural and neural responses to emotional valence. The results largely support this hypothesis, indicating that emotional word processing in L2 is characterised by reduced sensitivity to emotional valence at later stages of processing.

At the behavioural level, no significant differences in accuracy or response times were observed between emotional and neutral words, supporting the third hypothesis of a general behavioural response in L2. When comparing negative and positive words, no differences in response times were found, although negative words were recognised more accurately. This finding does not support the prediction of an advantage for positive words in L2, and contrasts from the clear behavioural differentiation observed in L1. It therefore indicates that emotional words do not consistently modulate behavioural responses in L2, with effects appearing weaker than those observed in L1, corroborating the expectation of reduced behavioural sensitivity in an L2.

These behavioural findings align with previous work showing that emotional L2

words often fail to elicit processing advantages typically associated with emotional content, both in auditory (e.g., Caldwell-Harris & Ayçiçeği-Dinn, 2009; Harris et al., 2003), and written modalities (e.g., Chen et al., 2015; Eilola et al., 2007; Pavlenko, 2012; Segalowitz et al., 2008). The present study thus corroborates previous evidence from auditory emotional word processing, reflecting reduced emotional engagement and increased cognitive demands in L2. However, this pattern contrasts with the notion that positive words should be recognized more accurately, due to their earlier acquisition in L2 (e.g., Ponari et al., 2017).

At the neural level, emotional words evoked larger LPC amplitudes than neutral words in L2, although this effect was attenuated relative to L1. This finding corroborates the third hypothesis of reduced emotional engagement at a neural level. Further exploration of this effect revealed that positive words elicited responses comparable to neutral words, whereas negative words showed increased LPC responses relative to neutral words. However, no significant difference arose from the comparison between negative and positive words. Together, these results suggest that emotional words are still processed in L2, but that neural responses show reduced sensitivity to differences in valence.

This pattern is consistent with emotional detachment, suggesting that emotional concepts are less strongly grounded due to differences in age of acquisition and context of learning (e.g., Caldwell-Harris, 2014; Harris et al., 2006; Sheikh & Titone, 2016). Because L2 emotional words are typically acquired in emotionally neutral contexts and after the maturation of emotional regulation systems, their semantic representations are less tightly linked to emotional experience. Fewer associative connections are therefore established between words and their emotional resonance (Pavlenko, 2012). As a result, emotional words may not elicit distinct emotional responses (Altarriba, 2003; Harris et al., 2006), yielding comparable levels of emotional activation across valence categories in L2, albeit attenuated compared to L1 (e.g., Chen et al., 2015; Conrad et al., 2011).

In line with this reduced emotional grounding, the absence of a clear differentiation between negative and positive words further supports the notion of weakened semantic-emotional integration (Chen et al., 2015; Conrad et al., 2011). Rather than selectively prioritising negative words, as observed in L1, emotional processing in L2 appears to occur in a more uniform and disembodied manner (e.g., Pavlenko, 2012). Because emotional concepts are less strongly established, their emotional meaning and perception may be more ambiguous in L2, particularly when conceptual representations are less readily accessible (see Brooks et al., 2017 for a meta-analysis on emotional word ambiguity independent of L2 context).

Moreover, positive words tend to provide less distinct valence cues and are often perceived as neutral (e.g., Delaney-Busch et al., 2016). Negative words, by contrast, are typically more unambiguous and evolutionarily salient (e.g., Delaney-Busch et al., 2016; Lang et al., 1997), making them easier to identify. The present findings demonstrated this; negative words were recognised more accurately. However, they did not evoke stronger emotional responses compared with positive words. Thus, while bilinguals may access the semantic content of negative L2 words, these words fail to elicit distinct emotional reactions (Dewaele, 2004, 2008), reinforcing the idea that the L2 is less deeply embedded in emotional experiences.

This reduced differentiation could also reflect more effortful processing of emotional meaning in L2 (Chen et al., 2015; Conrad et al., 2011; Hinojosa et al., 2010; Opitz & Degner, 2010). Emotional meaning may be less automatically and less distinctly activated, potentially requiring more effortful evaluation (e.g., Segalowitz et al., 2008). The increased LPC response for negative words might therefore reflect enhanced emotional engagement or sustained re-evaluation of negative content in L2 at later processing stages (Jończyk et al., 2016), associated with greater cognitive demands. Consequently, emotion effects for positive words may be attenuated by the presence of highly negative stimuli. If negative words were

removed from the stimulus set, a clearer emotion effect for positive words might emerge, even in an L2 (e.g., Tang et al., 2024).

Overall, language plays a decisive role in evoking emotional experiences. Emotional engagement is attenuated in L2, reflecting distinct behavioural and neural activity, and no differentiation between negative and positive words. Word valence affects emotional processing in both languages, but less pronounced in later-acquired languages. The reduced semantic-emotional integration in L2 appears to result in diminished emotional engagement relative to L1. Importantly, this study extends prior research on emotional word processing to the auditory modality. While emotional words, in particular negative ones, hold a special status in L1, this effect is attenuated in L2. Emotional word processing therefore appears to be strongly language-dependent.

5.3 Limitations and future research

The present study makes an important contribution to understanding L1 compared to L2 emotional word processing in the auditory modality, while also highlighting avenues for future research. These considerations can be broadly divided into theoretical and methodological aspects.

From a theoretical perspective, the present study focused on late lexical stages of emotional word processing, specifically the LPC, which is consistently modulated by emotional content. Earlier pre-lexical components, such as the N1-P1, N2-P2 and the EPN, are also sensitive to emotional words in the written modality (e.g., González-Villar et al., 2014; Kissler et al., 2008). Future research could therefore examine whether listening to emotional speech modulates early attentional prioritization of emotional words and whether these early-stage effects interact with later stages (Jończyk et al., 2016; Tang et al., 2024). This is particularly relevant as early components provide a neural correlate for the rapid detection advantages observed for negative words in the behavioral data. Auditory studies have already shown auditory EPN effects for prosodic and semantic tasks e.g., Czigler et al., 2007; Jaspers-Fayer et al., 2012; Mittermeier et al., 2010), suggesting that examining these early stages could yield additional insights into L2 processing.

While the current study provides valuable insights into auditory emotional word processing, it remains challenging to disentangle the contributions of emotional engagement from general cognitive load. This is particularly evident in L2, where increased cognitive demands may co-occur with diminished emotional engagement (Imbault, 2020; Sugita-McEown et al., 2024). The behavioral data may provide indirect evidence of increased processing demands, but the present data do not allow the distinction between emotional attenuation and cognitive effort at the neural level, as the LPC is primarily involved in emotional processing. Future research could therefore incorporate more direct indices of cognitive load (e.g., pupil dilation, dual-task paradigms) to better distinguish the underlying mechanisms within the auditory modality. Addressing this would clarify whether observed effects reflect emotional resonance, increased attentional demand, or a combination of both.

From a methodological perspective, the study extended emotional word processing research to the auditory modality, offering a foundation for future direct comparisons across modalities. While the results are consistent with previous findings in L2 reading, future work could investigate whether listening elicits stronger neural responses than reading, as suggested by physiological responses in skin conductance and pupillometry research (Harris et al., 2003; Harris, 2004; Yao et al., 2023).

The valence judgment task used here may have amplified the differentiation of emotional effects across languages. The explicit categorisation of emotional valence likely increased automatic vigilance and sustained emotional processing (e.g., Delaney-Busch et al.,

2016; Estes & Verges, 2007; Fischler & Bradley 2006; Gonzalez-Villar et al., 2014). In L1, this may have facilitated automatic access to emotional meaning, whereas in L2 it may have increased cognitive effort, attenuating valence-specific differentiation. Moreover, because the task included all three valence categories, the highly aversive nature of negative words may have disproportionally captured more attention, potentially driving the dominance of the "*negative brain*" (Carretié et al., 2008b). To determine whether these effects reflect generalise beyond this paradigm, future studies could employ alternative task designs.

Furthermore, emotion-laden and emotion-label words were not distinctly categorized during stimulus selection. Hence, this design reflects naturalistic language processing, where both word types co-occur inconsistently. The observed effect may, however, be biased towards a particular word condition, considering that emotion-label and emotion-laden words have been shown to be processed differently, eliciting distinct neural responses in written text (e.g., Tang et al., 2024; Wu et al., 2019; Zhang et al., 2017). To verify this, future research could systematically distinguish between them to examine their impact on the processing of emotional words in the auditory modality.

Although words were presented in a monotonous tone to isolate semantic effects, prosody plays an important role in conveying emotion (Kotz & Paulmann, 2007; Paulmann & Kotz, 2008a). Future research could explore interactions between prosody and semantics, including comparisons between human and artificial voices. Accordingly, it could determine whether the observed emotion effects generalize beyond a single speaker. Likewise, context can shape emotional responses (Bąk, 2013; Bayer et al., 2010; Ding et al., 2014; Erickson & Schulkin, 2003; Jończyk et al., 2016; Zhang et al., 2006, 2010). While decontextualized words allowed for a controlled examination of emotional processing, future work could investigate how discourse context, facial expressions and environmental factors influence emotional processing. Such effects have been examined in auditory emotional processing in monolingual populations (e.g., Gerdes et al., 2014; Hernández-Gutiérrez et al., 2022; Maquate et al., 2023), their role in bilingual contexts remains to be explored.

Naturalistic contexts also introduce external sources of uncertainty, such as environmental noise, affecting both speech processing (Bidelman & Dexter, 2015; Brouwer et al., 2012) and emotional responses (Amorese et al., 2025). To which extent such external cues influence emotional word processing remains unclear. It is particularly relevant to study, given that environmental noise introduces perceptual uncertainty, whereas bilingualism introduces an internal uncertainty with differences in emotional resonance across languages.

Finally, while the current study provides a first step in examining auditory emotional word processing, future research could expand on these findings by incorporating alternative EEG measures such as neural oscillations, which may better capture the dynamic integration of multimodal information over time (Drijvers & Mazzini, 2023; Rossi et al., 2022; Symons et al., 2016).

6. Conclusion

The present study extends previous evidence of emotional detachment in L2 to the auditory modality, by providing behavioural and neural evidence. It examined emotional responses in processing negative, neutral and positive spoken words in both L1 and L2 in late Dutch-English bilinguals. The results demonstrated the presence of a language-dependent emotion effect in late lexical processing and highlighted dissimilar neural processing patterns towards emotional words between L1 and L2.

Emotional words elicited larger LPC amplitudes than neutral words in both languages, reflecting stronger emotional responses. However, this effect was attenuated in L2. In L1, negative words triggered stronger responses than positive words, consistent with the "*negativity bias*" (Ito et al., 1998), whereas in L2, no difference between negative and positive words was observed, indicating reduced emotional engagement and emotional detachment.

Overall, negative emotions are prioritized in L1 due to their evolutionary relevance, while emotional resonance is diminished in later-acquired languages. These findings extend prior research by showing that emotional detachment also occurs in the auditory modality, highlighting the importance of studying spoken stimuli to understand emotional word processing.

References

Altarriba, J. (2003). Does cariño equal "liking"? *International Journal of Bilingualism, 7*(3), 305–322. https://doi.org/10.1177/13670069030070030501

Amorese, T., Cuciniello, M., Alterio, A., Pepe, D., Scharenborg, O., Cordasco, G., & Esposito, A. (2025). Exploring the impact of noise, language familiarity, and experimental settings on emotion recognition. *Frontiers in Psychology, 16*, 1548975. https://doi.org/10.3389/fpsyg.2025.1548975

Astésano, C., Besson, M., & Alter, K. (2003). Brain potentials during semantic and prosodic processing in French. *Cognitive Brain Research, 18*(2), 172–184. https://doi.org/10.1016/j.cogbrainres.2003.10.002

Baayen, R., Davidson, D., & Bates, D. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412. https://doi.org/10.1016/j.jml.2007.12.005

Bąk, H. (2013). Empathy and distress: Internal and external context dependency of emotion term selection. *Poznań Studies in Contemporary Linguistics, 49*, 137–165. https://doi.org/10.1515/psicl2013-0005

Barr, D. J. (2013). Random effects structure for testing interactions in linear mixed-effects models. *Frontiers in Psychology, 4*. https://doi.org/10.3389/fpsyg.2013.00328

Barrett, L. F., Bliss-Moreau, E., Duncan, S. L., Rauch, S. L., & Wright, C. I. (2007). The amygdala and the experience of affect. *Social Cognitive and Affective Neuroscience, 2*(2), 73–83. https://doi.org/10.1093/scan/nsl042

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2018). Parsimonious mixed models. *arXiv*. https://doi.org/10.48550/arxiv.1506.04967

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5*(4), 323–370. https://doi.org/10.1037/1089-2680.5.4.32

Baumeister, J. C., Foroni, F., Conrad, M., Rumiati, R. I., & Winkielman, P. (2017). Embodiment and emotional memory in first vs. second language. *Frontiers in Psychology, 8*, 394. https://doi.org/10.3389/fpsyg.2017.00394

Bayer, M., Sommer, W., & Schacht, A. (2010). Reading emotional words within sentences: The impact of arousal and valence on event-related potentials. *International Journal of Psychophysiology, 78*(3), 299–307. https://doi.org/10.1016/j.ijpsycho.2010.09.004

Bayer, M., & Schacht, A. (2014). Event-related brain responses to emotional words, pictures, and faces - a cross-domain comparison. *Frontiers in Psychology, 5*, 1106. https://doi.org/10.3389/fpsyg.2014.01106

Bidelman, G. M., & Dexter, L. (2015). Bilinguals at the "cocktail party": Dissociable neural activity in auditory– linguistic brain regions reveals neurobiological basis for nonnative listeners' speech-in-noise recognition deficits. *Brain and Language, 143*, 32–41. https://doi.org/10.1016/j.bandl.2015.02.002

Bloom, L., & Beckwith, R. (1989). Talking with feeling: Integrating affective and linguistic expression in early language development. *Cognition & Emotion, 3*(4), 313–342. https://doi.org/10.1080/02699938908412711

Boersma, P. (2001). PRAAT, a system for doing phonetics by computer. *Glot International, 5*(9/10), 341–345.

Bolker, B. M. (2008). *Ecological Models and Data in R*. Princeton University Press. https://doi.org/10.1515/9781400840908

Bradley, M. M. (2000). Emotion and motivation. In J. T. Cacioppo, L. G. Tassinary, & G. G.

Berntson (Eds.), *Handbook of psychophysiology* (2nd ed., pp. 602–642). Cambridge University Press.
Brooks, J. A., Shablack, H., Gendron, M., Satpute, A. B., Parrish, M. H., & Lindquist, K. A. (2016). The role of language in the experience and perception of emotion: a neuroimaging meta-analysis. *Social Cognitive and Affective Neuroscience, 12*(2), nsw121. https://doi.org/10.1093/scan/nsw121
Brouwer, S., Van Engen, K.J., Calandruccio, L., & Bradlow, A.R. (2012). Linguistic contributions to speech-on-speech masking for native and non-native listeners: Language familiarity and semantic content. *The Journal of the Acoustical Society of America, 131*(2), 1449-1464. https://doi.org/10.1121/1.3675943
Brysbaert, M., Warriner, A. B., & Kuperman, V. (2013). Concreteness ratings for 40 thousand generally known English word lemmas. *Behavior Research Methods, 46*(3), 904–911. https://doi.org/10.3758/s13428-013-0403-5
Brysbaert, M., Stevens, M., De Deyne, S., Voorspoels, W., & Storms, G. (2014). Norms of age of acquisition and concreteness for 30,000 Dutch words. *Acta Psychologica, 150*, 80–84. https://doi.org/10.1016/j.actpsy.2014.04.010
Cacioppo, J. T., & Berntson, G. G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological Bulletin, 115*(3), 401–423. https://doi.org/10.1037/0033-2909.115.3.401
Cacioppo, J. T., & Berntson, G. G. (1999). The affect system: Architecture and operating characteristics. *Current directions in psychological science, 8*(5), 133-137. https://doi.org/10.1111/1467-8721.00031
Caldwell-Harris, C. L., & Ayçiçeği-Dinn, A. (2009). Emotion and lying in a non-native language. *International Journal of Psychophysiology, 71*(3), 193–204. https://doi.org/10.1016/j.ijpsycho.2008.09.006
Caldwell-Harris, C. L. (2014). Emotionality differences between a native and foreign language: theoretical implications. *Frontiers in Psychology*, *5,* 1055. https://doi.org/10.3389/fpsyg.2014.01055
Carretié, L., Hinojosa, J. A., Albert, J., López-Martín, S., De La Gándara, B. S., Igoa, J. M., & Sotillo, M. (2008a). Modulation of ongoing cognitive processes by emotionally intense words. *Psychophysiology, 45*(2), 188–196. https://doi.org/10.1111/j.1469-8986.2007.00617.x
Carretié, L., Albert, J., López-Martín, S., & Tapia, M. (2008b). Negative brain: An integrative review on the neural processes activated by unpleasant stimuli. *International Journal of Psychophysiology, 71*(1), 57–63. https://doi.org/10.1016/j.ijpsycho.2008.07.006
Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin, 25*(2), 215–224. https://doi.org/10.1177/0146167299025002007
Chen, P., Lin, J., Chen, B., Lu, C., & Guo, T. (2015). Processing emotional words in two languages with one brain: ERP and fMRI evidence from Chinese–English bilinguals. *Cortex, 71*, 34–48. https://doi.org/10.1016/j.cortex.2015.06.002
Citron, F. M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language, 122*(3), 211–226. https://doi.org/10.1016/j.bandl.2011.12.007
Conrad, M., Recio, G., & Jacobs, A. M. (2011). The Time Course of Emotion Effects in First and Second Language Processing: A Cross Cultural ERP Study with German-Spanish Bilinguals. *Frontiers in Psychology, 2*, 351. https://doi.org/10.3389/fpsyg.2011.00351
Czigler, I., Cox, T. J., Gyimesi, K., & Horváth, J. (2007). Event-related potential study to

aversive auditory stimuli. *Neuroscience Letters, 420*(3), 251–256. https://doi.org/10.1016/j.neulet.2007.05.007
Damasio, A. (2001). Fundamental feelings. *Nature, 413*(6858), 781. https://doi.org/10.1038/35101669
Degner, J., Doycheva, C., & Wentura, D. (2011). It matters how much you talk: On the automaticity of affective connotations of first and second language words. *Bilingualism Language and Cognition, 15*(1), 181–189. https://doi.org/10.1017/s1366728911000095
Delaney-Busch, N., Wilkie, G., & Kuperberg, G. (2016). Vivid: How valence and arousal influence word processing under different task demands. *Cognitive Affective & Behavioral Neuroscience, 16*(3), 415–432. https://doi.org/10.3758/s13415-016-0402-y
Dewaele, J. (2004). The emotional force of swearwords and taboo words in the speech of multilinguals. *Journal of Multilingual and Multicultural Development, 25*(2–3), 204–222. https://doi.org/10.1080/01434630408666529
Dewaele, J. M. (2008). The emotional weight of I love you in multilinguals' languages. *Journal of Pragmatics, 40*(10), 1753–1780. https://doi.org/10.1016/j.pragma.2008.03.002
Dewaele, J. (2010). *Emotions in multiple languages*. Basingstoke, England: Palgrave Macmillan UK eBooks. https://doi.org/10.1057/9780230289505
Ding, J., Wang, L., & Yang, Y. (2014). The dynamic influence of emotional words on sentence processing. *Cognitive Affective & Behavioral Neuroscience, 15*(1), 55–68. https://doi.org/10.3758/s13415-014-0315-6
Drijvers, L., & Mazzini, S. (2023). Neural Oscillations in Audiovisual Language and Communication. In S. Murray (Eds.), *Oxford research encyclopedia of neuroscience* (pp. 1-45). Oxford University Press. https://doi.org/10.1093/acrefore/9780190264086.013.455
Eilola, T. M., Havelka, J., & Sharma, D. (2007). Emotional activation in the first and second language. *Cognition & Emotion, 21*(5), 1064–1076. https://doi.org/10.1080/02699930601054109
Erickson, K., & Schulkin, J. (2003). Facial expressions of emotion: A cognitive neuroscience perspective. *Brain and Cognition, 52*(1), 52–60. https://doi.org/10.1016/s0278-2626(03)00008-3
Espuny, J., Jiménez-Ortega, L., Casado, P., Fondevila, S., Muñoz, F., Hernández-Gutiérrez, D., & Martín-Loeches, M. (2018). Event-related brain potential correlates of words' emotional valence irrespective of arousal and type of task. *Neuroscience Letters, 670*, 83–88. https://doi.org/10.1016/j.neulet.2018.01.050
Estes, Z., & Adelman, J. S. (2008). Automatic vigilance for negative words is categorical and general. *Emotion, 8*(4), 453–457. https://doi.org/10.1037/a0012887
Estes, Z., & Verges, M. (2008). Freeze or flee? Negative stimuli elicit selective responding. *Cognition, 108*(2), 557–565. https://doi.org/10.1016/j.cognition.2008.03.003
Ferré, P., García, T., Fraga, I., Sánchez-Casas, R., & Molero, M. (2010). Memory for emotional words in bilinguals: Do words have the same emotional intensity in the first and in the second language? *Cognition & Emotion, 24*(5), 760–785. https://doi.org/10.1080/02699930902985779
Ferré, P., Guasch, M., Stadthagen-Gonzalez, H., & Comesaña, M. (2022). Love me in L1, but hate me in L2: How native speakers and bilinguals rate the affectivity of words when feeling or thinking about them. *Bilingualism: Language and Cognition, 25*(5), 786–800. https://doi.org/10.1017/s1366728922000189
Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: words, phrases, and task effects. *Progress in Brain Research, 156*, 185–203.

https://doi.org/10.1016/s0079-6123(06)56009-1
Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011). Time course of implicit processing and explicit processing of emotional faces and emotional words. *Biological Psychology, 87*(2), 265–274. https://doi.org/10.1016/j.biopsycho.2011.03.008
Gerdes, A. B. M., Wieser, M. J., & Alpers, G. W. (2014). Emotional pictures and sounds: a review of multimodal interactions of emotion cues in multiple domains. *Frontiers in Psychology, 5*, 1351. https://doi.org/10.3389/fpsyg.2014.01351
González-Villar, A. J., Triñanes, Y., Zurrón, M., & Carrillo-De-La-Peña, M. T. (2014). Brain processing of task-relevant and task-irrelevant emotional words: An ERP study. *Cognitive Affective & Behavioral Neuroscience, 14*(3), 939–950. https://doi.org/10.3758/s13415-013-0247-6
Grosjean, F. (2024). *On Bilinguals and Bilingualism*. Cambridge University Press. https://doi.org/10.1017/9781009210409
Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology*, *120*(3), 505–510. https://doi.org/10.1016/j.clinph.2008.11.028
Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2011). ERPs and the study of emotion. In S. J. Luck, & E. S. Kappenman (Eds.), *The Oxford handbook of event-related potential components* (pp. 441–472). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195374148.013.0222
Harris, C. L., Ayçiçeği, A., & Gleason, J. B. (2003). Taboo words and reprimands elicit greater autonomic reactivity in a first than in a second language. *Applied Psycholinguistics, 24*(4), 561–578. https://doi.org/10.1017/S0142716403000286
Harris, C. L. (2004). Bilingual speakers in the lab: Psychophysiological measures of emotional reactivity. *Journal of Multilingual and Multicultural Development, 25*(2–3), 223–247. https://doi.org/10.1080/01434630408666530
Harris, C. L., Gleason, J. B., & Ayçiçeki, A. (2006). When is a first language more emotional? Psychophysiological evidence from bilingual speakers. In A. Pavlenko (Ed.), *Bilingual minds: Emotional experience, expression, and representation* (pp. 257–83). Clevedon, England: Multilingual Matters.
Herbert, C., Kissler, J., Junghöfer, M., Peyk, P., & Rockstroh, B. (2006). Processing of emotional adjectives: Evidence from startle EMG and ERPs. *Psychophysiology, 43*(2), 197–206. https://doi.org/10.1111/j.1469-8986.2006.00385.x
Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology, 45*(3), 487–498. https://doi.org/10.1111/j.1469-8986.2007.00638.x
Hernández-Gutiérrez, D., Muñoz, F., Khosrowtaj, Z., Sommer, W., Jiménez-Ortega, L., Rahman, R. A., Sánchez- García, J., Casado, P., Fondevila, S., Espuny, J., & Martín-Loeches, M. (2022). How the speaker's emotional facial expressions may affect language comprehension. *Language, Cognition and Neuroscience, 38*(10), 1478–1491. https://doi.org/10.1080/23273798.2022.2130945
Hinojosa, J. A., Méndez-Bértolo, C., & Pozo, M. A. (2010). Looking at emotional words is not the same as reading emotional words: Behavioral and neural correlates. *Psychophysiology*, *47*(4), 748–757. https://doi.org/10.1111/j.1469-8986.2010.00982.x
Hofmann, M. J., Kuchinke, L., Tamm, S., Võ, M. L. H., & Jacobs, A. M. (2009). Affective processing within 1/10th of a second: High arousal is necessary for early facilitative processing of negative but not positive words. *Cognitive Affective & Behavioral Neuroscience, 9*(4), 389–397. https://doi.org/10.3758/9.4.389
Holcomb, P. J., & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and*

Cognitive Processes, 5(4), 281–312. https://doi.org/10.1080/01690969008407065
Holcomb, P. J., Coffey, S. A., & Neville, H. J. (1992). Visual and auditory sentence processing: A developmental analysis using event-related brain potentials. *Developmental Neuropsychology, 8*(2–3), 203–241. https://doi.org/10.1080/87565649209540525
Holt, D. J., Lynn, S. K., & Kuperberg, G. R. (2008). Neurophysiological correlates of comprehending emotional meaning in context. *Journal of Cognitive Neuroscience, 21*(11), 2245–2262. https://doi.org/10.1162/jocn.2008.21151
Iacozza, S., Costa, A., & Duñabeitia, J. A. (2017). What do your eyes reveal about your foreign language? Reading emotional sentences in a native and foreign language. *PLoS ONE, 12*(10), e0186027. https://doi.org/10.1371/journal.pone.0186027
Imbault, C., Titone, D., Warriner, A. B., & Kuperman, V. (2020). How are words felt in a second language: Norms for 2,628 English words for valence and arousal by L2 speakers. *Bilingualism: Language and Cognition, 24*(2), 281–292. https://doi.org/10.1017/s1366728920000474
Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*(4), 887–900. https://doi.org/10.1037/0022-3514.75.4.887
Ito, T. A., & Cacioppo, J. T. (2000). Electrophysiological evidence of implicit and explicit categorization processes. *Journal of Experimental Social Psychology, 36*(6), 660–676. https://doi.org/10.1006/jesp.2000.1430
Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*(4), 434–446. https://doi.org/10.1016/j.jml.2007.11.007
Jakimik, J., & Glenberg, A. (1990). Verbal learning meets psycholinguistics: Modality effects in the comprehension of anaphora. *Journal of Memory and Language, 29*(5), 582–590. https://doi.org/10.1016/0749-596x(90)90053-3
Jankowiak, K., & Korpal, P. (2017). On modality effects in bilingual emotional language processing: Evidence from galvanic skin response. *Journal of Psycholinguistic Research, 47*(3), 663–677. https://doi.org/10.1007/s10936-017-9552-5
Jasper, H. H. (1958). The 10/20 international electrode system. *Electroencephalography and Clinical Neurophysiology*, *10*(2), 370–375.
Jaspers-Fayer, F., Ertl, M., Leicht, G., Leupelt, A., & Mulert, C. (2012). Single-trial EEG–fMRI coupling of the emotional auditory early posterior negativity. *NeuroImage, 62*(3), 1807–1814. https://doi.org/10.1016/j.neuroimage.2012.05.018
Jończyk, R. (2016). *Affect-language interactions in native and non-native English speakers.* Springer International Publishing AG. https://doi.org/10.1007/978-3-319-47635-3
Jończyk, R., Boutonnet, B., Musiał, K., Hoemann, K., & Thierry, G. (2016). The bilingual brain turns a blind eye to negative statements in the second language. *Cognitive Affective & Behavioral Neuroscience, 16*(3), 527–540. https://doi.org/10.3758/s13415-016-0411-x
Jończyk, R., Naranowicz, M., Bel-Bahar, T. S., Jankowiak, K., Korpal, P., Bromberek-Dyzman, K., & Thierry, G. (2024). Brain potentials reveal reduced sensitivity to negative content during second language production. *Bilingualism Language and Cognition, 28*(1), 54–65. https://doi.org/10.1017/s1366728924000075
Jongenburger, W., & Van Heuven, V. J. (1991). The Distribution of (Word Initial) Glottal Stop in Dutch. *Linguistics in The Netherlands, 8,* 101–110. https://doi.org/10.1075/avt.8.13jon

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research, 1148*, 138–148. https://doi.org/10.1016/j.brainres.2007.02.044

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). The role of emotional valence for the processing of facial and verbal stimuli - positivity or negativity bias? *Frontiers in Psychology, 10*, 1654. https://doi.org/10.3389/fpsyg.2019.01654

Kazanas, S. A., & Altarriba, J. (2016). Emotion word processing: Effects of word type and valence in Spanish–English bilinguals. *Journal of Psycholinguistic Research, 45*(2), 395–406. https://doi.org/10.1007/s10936-015-9357-3

Keuleers, E., Brysbaert, M., & New, B. (2010). SUBTLEX-NL: A new measure for Dutch word frequency based on film subtitles. *Behavior Research Methods, 42*(3), 643–650. https://doi.org/10.3758/brm.42.3.643

Kissler, J., Herbert, C., Peyk, P., & Junghofer, M. (2007). Buzzwords: Early cortical responses to emotional words during reading. *Psychological Science, 18*(6), 475–480. https://doi.org/10.1111/j.1467-9280.2007.01924.x

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2008). Emotion and attention in visual word processing: An ERP study. *Biological Psychology, 80*(1), 75–83. https://doi.org/10.1016/j.biopsycho.2008.03.004

Kissler, J., & Herbert, C. (2012). Emotion, Etmnooi, or Emitoon? – Faster lexical access to emotional than to neutral words during reading. *Biological Psychology, 92*(3), 464–479. https://doi.org/10.1016/j.biopsycho.2012.09.004

Kotz, S. A., & Paulmann, S. (2007). When emotional prosody and semantics dance cheek to cheek: ERP evidence. *Brain Research, 1151*, 107–118. https://doi.org/10.1016/j.brainres.2007.03.015

Kousta, S., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition, 112*(3), 473–481. https://doi.org/10.1016/j.cognition.2009.06.007

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). LMERTest Package: Tests in Linear Mixed Effects models. *Journal of Statistical Software, 82*(13). https://doi.org/10.18637/jss.v082.i13

LaBar, K., & Phelps, E. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science, 9*(6), 490–493. https://doi.org/10.1111/1467-9280.00090

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. Balaban (Eds.), *Motivated attention: Affect, activation, and action* (pp. 97–135). Mahwah, NJ: Erlbaum.

Lang, P. J. (2000). Emotion and motivation: Attention, perception, and action. *Journal of Sport and Exercise Psychology, 22*(1), S122–S140. https://doi.org/10.1123/jsep.22.s1.s122

Lemhöfer, K., & Broersma, M. (2011). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods, 44*(2), 325–343. https://doi.org/10.3758/s13428-011-0146-0

Lenth, R. & Piaskowski, J. (2026). emmeans: Estimated Marginal Means, aka Least-Squares Means. *R package version 2.0.2*, https://CRAN.R-project.org/package=emmeans

Li, P., Zhang, F., Yu, A., & Zhao, X. (2019). Language History Questionnaire (LHQ3): An enhanced tool for assessing multilingual experience. *Bilingualism: Language and Cognition, 23*(5), 938–944. https://doi.org/10.1017/s1366728918001153

Lindquist, K. A., Satpute, A. B., & Gendron, M. (2015). Does language do more than communicate emotion? *Current Directions in Psychological Science, 24*(2), 99–108. https://doi.org/10.1177/0963721414553440

Lindquist, K. A. (2017). The role of language in emotion: existing evidence and future directions. *Current Opinion in Psychology*, *17*, 135–139. https://doi.org/10.1016/j.copsyc.2017.07.006
Liu, B., Jin, Z., Wang, Z., & Hu, Y. (2009). The interaction between pictures and words: evidence from positivity offset and negativity bias. *Experimental Brain Research, 201*(2), 141–153. https://doi.org/10.1007/s00221-009-2018-8
Luck, S. J. (2014). *An introduction to the event-related potential technique* (2nd ed.). MIT Press.
Maquate, K., Kissler, J., & Knoeferle, P. (2023). Speakers' emotional facial expressions modulate subsequent multi- modal language processing: ERP evidence. *Language, Cognition and Neuroscience, 38*(10), 1492–1513. https://doi.org/10.1080/23273798.2022.2108089
Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods, 44*(2), 314–324. https://doi.org/10.3758/s13428-011-0168-7
Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing Type I error and power in linear mixed models. *Journal of Memory and Language, 94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001
Mittermeier, V., Leicht, G., Karch, S., Hegerl, U., Möller, H., Pogarell, O., & Mulert, C. (2010). Attention to emotion: auditory-evoked potentials in an emotional choice reaction task and personality traits as assessed by the NEO FFI. *European Archives of Psychiatry and Clinical Neuroscience, 261*(2), 111–120. https://doi.org/10.1007/s00406-010-0127-9
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
Naranowicz, M., & Jankowiak, K. (2024). A negative mood facilitates complex semantic processing in a second language. *Applied Psycholinguistics, 45*(6), 979–999. https://doi.org/10.1017/s0142716424000365
Nasrallah, M., Carmel, D., & Lavie, N. (2009). Murder, she wrote: Enhanced sensitivity to negative word valence. *Emotion, 9*(5), 609–618. https://doi.org/10.1037/a0016305
Naumann, E., Bartussek, D., Diedrich, O., & Laufer, M. E. (1992). Assessing cognitive and affective information processing functions of the brain by means of the late positive complex of the event-related potential. *Journal of Psychophysiology, 6(*4), 285–298.
Nunez, P. L., & Srinivasan, R. (2006). *Electric fields of the brain: the neurophysics of EEG*. Oxford university press.
Öhman, A. (2005). The role of the amygdala in human fear: Automatic detection of threat. *Psychoneuroendocrinology, 30*(10), 953–958. https://doi.org/10.1016/j.psyneuen.2005.03.019
Oldfield, R. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4
Opitz, B., & Degner, J. (2012). Emotionality in a second language: It's a matter of time. *Neuropsychologia, 50*(8), 1961–1967. https://doi.org/10.1016/j.neuropsychologia.2012.04.021
Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsychologia, 49*(9), 2766–2775. https://doi.org/10.1016/j.neuropsychologia.2011.06.005
Paulmann, S., & Kotz, S. A. (2008a). Early emotional prosody perception based on different

speaker voices. *Neuroreport, 19*(2), 209–213. https://doi.org/10.1097/wnr.0b013e3282f454db
Paulmann, S., & Kotz, S. A. (2008b). An ERP investigation on the temporal dynamics of emotional prosody and emotional semantics in pseudo- and lexical-sentence context. *Brain and Language, 105*(1), 59–69. https://doi.org/10.1016/j.bandl.2007.11.005
Pavlenko, A. (2005). *Emotions and bilingualism*. Cambridge University Press.
Pavlenko, A. (2008). Emotion and emotion-laden words in the bilingual lexicon. *Bilingualism Language and Cognition, 11*(2), 147–164. https://doi.org/10.1017/s1366728908003283
Pavlenko, A. (2012). Affective processing in bilingual speakers: Disembodied cognition? *International Journal of Psychology, 47*(6), 405–428. https://doi.org/10.1080/00207594.2012.743665
Peeters, G., & Czapinski, J. (1990). Positive-negative asymmetry in evaluations: The distinction between affective and informational negativity effects. *European Review of Social Psychology, 1*(1), 33–60. https://doi.org/10.1080/14792779108401856
Peeters, F.P.M.L., Ponds, R.W.H.M., & Vermeeren, M.T.G. (1996). Affectiviteit en zelfbeoordeling van depressie en angst. *Tijdschrift voor Psychiatrie, 38*, 240-250.
Pell, M. D. (2005). Cerebral mechanisms for understanding emotional prosody in speech. *Brain and Language, 96*(2), 221–234. https://doi.org/10.1016/j.bandl.2005.04.007
Ponari, M., Rodríguez-Cuadrado, S., Vinson, D., Fox, N., Costa, A., & Vigliocco, G. (2015). Processing advantage for emotional words in bilingual speakers. *Emotion, 15*(5), 644–652. https://doi.org/10.1037/emo0000061
Ponari, M., Norbury, C. F., & Vigliocco, G. (2017). Acquisition of abstract concepts is influenced by emotional valence. *Developmental Science, 21*(2). https://doi.org/10.1111/desc.12549
Pratto, F., & John, O. P. (1991). Automatic vigilance: The attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61*(3), 380–391. https://doi.org/10.1037/0022-3514.61.3.380
Puntoni, S., De Langhe, B., & Van Osselaer, S. M. J. (2008). Bilingualism and the emotional intensity of advertising language. *Journal of Consumer Research, 35*(6), 1012–1025. https://doi.org/10.1086/595022
Rossi, E., Soares, S. M. P., Prystauka, Y., Nakamura, M., & Rothman, J. (2022). Riding the (brain) waves! Using neural oscillations to inform bilingualism research. *Bilingualism Language and Cognition, 26*(1), 202–215. https://doi.org/10.1017/s1366728922000451
Rothermund, K., Wentura, D., & Bak, P. M. (2001). Automatic attention to stimuli signalling chances and dangers: Moderating effects of positive and negative goal and action contexts. *Cognition & Emotion, 15*(2), 231–248. https://doi.org/10.1080/02699930126213
Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161–1178. https://doi.org/10.1037/h0077714
Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110*(1), 145–172. https://doi.org/10.1037/0033-295x.110.1.145
Schacht, A., & Sommer, W. (2009). Time course and task dependence of emotion effects in word processing. *Cognitive Affective & Behavioral Neuroscience, 9*(1), 28–43. https://doi.org/10.3758/cabn.9.1.28
Segalowitz, N., Trofimovich, P., Gatbonton, E., & Sokolovskaya, A. (2008). Feeling affect in a second language. *The Mental Lexicon, 3*(1), 47–71. https://doi.org/10.1075/ml.3.1.05seg
Sharif, H., & Mahmood, S. (2023). Emotional processing in bilinguals: a systematic review

aimed at identifying future trends in neurolinguistics. *Humanities and Social Sciences Communications, 10*(1). https://doi.org/10.1057/s41599-023-01926-1
Sheikh, N. A., & Titone, D. (2015). The embodiment of emotional words in a second language: An eye-movement study. *Cognition & Emotion, 30*(3), 488–500. https://doi.org/10.1080/02699931.2015.1018144
Speed, L. J., & Brysbaert, M. (2023). Ratings of valence, arousal, happiness, anger, fear, sadness, disgust, and surprise for 24,000 Dutch words. *Behavior Research Methods, 56*(5), 5023–5039. https://doi.org/10.3758/s13428-023-02239-6
Sugita-McEown, M., Makuuchi, M., Naoe, T., Ellinger, J., Oga-Baldwin, W. L. Q., & McEown, K. (2024). An fMRI study examining the role of the extended amygdala and amygdala in emotion and inhibitory control in native versus second language processing. *PLoS ONE, 19*(11), e0310129. https://doi.org/10.1371/journal.pone.0310129
Sutton, T. M., Altarriba, J., Gianico, J. L., & Basnight-Brown, D. M. (2007). The automatic access of emotion: Emotional Stroop effects in Spanish–English bilingual speakers. *Cognition & Emotion, 21*(5), 1077–1090. https://doi.org/10.1080/02699930601054133
Symons, A. E., El-Deredy, W., Schwartze, M., & Kotz, S. A. (2016). The Functional Role of Neural Oscillations in Non-Verbal Emotional Communication. *Frontiers in Human Neuroscience, 10*, 239. https://doi.org/10.3389/fnhum.2016.00239
Tang, D., Li, X., Fu, Y., Wang, H., Li, X., Parviainen, T., & Kärkkäinen, T. (2024). Neural correlates of emotion-label vs. emotion-laden word processing in late bilinguals: evidence from an ERP study. *Cognition & Emotion*, *39*(7), 1576–1593. https://doi.org/10.1080/02699931.2024.2352584
Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin, 110*(1), 67–85. https://doi.org/10.1037/0033-2909.110.1.67
Toivo, W. & Scheepers, C. (2019). Pupillary responses to affective words in bilinguals' first versus second language. *PLoS ONE, 14*(4): e0210450. https://doi.org/10.1371/journal.pone.0210450
Unkelbach, C., Fiedler, K., Bayer, M., Stegmüller, M., & Danner, D. (2008). Why positive information is processed faster: The density hypothesis. *Journal of Personality and Social Psychology, 95*(1), 36–49. https://doi.org/10.1037/0022-3514.95.1.36
Van Heuven, W. J. B., Mandera, P., Keuleers, E., & Brysbaert, M. (2013). Subtlex-UK: A New and Improved Word Frequency Database for British English. *Quarterly Journal of Experimental Psychology, 67*(6), 1176–1190. https://doi.org/10.1080/17470218.2013.850521
Vélez-Uribe, I., & Rosselli, M. (2020). Electrophysiological correlates of emotion word processing in Spanish–English bilinguals. *Bilingualism Language and Cognition, 24*(1), 31–55. https://doi.org/10.1017/s136672892000036x
Vinson, D., Ponari, M., & Vigliocco, G. (2013). How does emotional content affect lexical processing? *Cognition & Emotion, 28*(4), 737–746. https://doi.org/10.1080/02699931.2013.851068
Vukovic, N., & Shtyrov, Y. (2014). Cortical motor systems are involved in second-language comprehension: Evidence from rapid mu-rhythm desynchronisation. *NeuroImage, 102*, 695–703. https://doi.org/10.1016/j.neuroimage.2014.08.039
Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods, 45*(4), 1191–1207. https://doi.org/10.3758/s13428-012-0314-x
Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality*

and Social Psychology, 54(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: The attention-grabbing power of approach- and avoidance-related social information. *Journal of Personality and Social Psychology, 78*(6), 1024–1037. https://doi.org/10.1037/0022-3514.78.6.1024

Wu, Y. J., & Thierry, G. (2012). How Reading in a Second Language Protects Your Heart. *Journal of Neuroscience, 32*(19), 6485–6489. https://doi.org/10.1523/jneurosci.6119-11.2012

Wu, C., Zhang, J., & Yuan, Z. (2019). An ERP investigation on the second language and emotion perception: the role of emotion word type. *International Journal of Bilingual Education and Bilingualism, 25*(2), 539–551. https://doi.org/10.1080/13670050.2019.1703895

Yang, J., Zeng, J., Meng, X., Zhu, L., Yuan, J., Li, H., & Yusoff, N. (2013). Positive words or negative words: Whose valence strength are we more sensitive to? *Brain Research, 1533*, 91–104. https://doi.org/10.1016/j.brainres.2013.08.020

Yao, Z., & Wang, Z. (2014). Concreteness of positive word contributions to affective priming: An ERP study. *International Journal of Psychophysiology, 93*(3), 275–282. https://doi.org/10.1016/j. ijpsycho.2014.06.005

Yao, Z., Yu, D., Wang, L., Zhu, X., Guo, J., & Wang, Z. (2016). Effects of valence and arousal on emotional word processing are modulated by concreteness: Behavioral and ERP evidence from a lexical decision task. *International Journal of Psychophysiology, 110*, 231–242. https://doi.org/10.1016/j.ijpsycho.2016.07.499

Yao, Y., Connell, K., & Politzer-Ahles, S. (2023). Hearing emotion in two languages: A pupillometry study of Cantonese–Mandarin bilinguals' perception of affective cognates in L1 and L2. *Bilingualism Language and Cognition, 26*(4), 795–808. https://doi.org/10.1017/s1366728922000931

Zhang, Q., Lawson, A., Guo, C., & Jiang, Y. (2006). Electrophysiological correlates of visual affective priming. *Brain Research Bulletin, 71*(1–3), 316–323. https://doi.org/10.1016/j.brainresbull.2006.09.023

Zhang, Q., Li, X., Gold, B. T., & Jiang, Y. (2010). Neural correlates of cross-domain affective priming. *Brain Research, 1329*, 142–151. https://doi.org/10.1016/j.brainres.2010.03.021

Zhang, D., He, W., Wang, T., Luo, W., Zhu, X., Gu, R., Li, H., & Luo, Y. (2014). Three stages of emotional word processing: an ERP study with rapid serial visual presentation. *Social Cognitive and Affective Neuroscience, 9(*12), 1897–1903. https://doi.org/10.1093/scan/nst188

Zhang, J., Wu, C., Meng, Y., & Yuan, Z. (2017). Different neural correlates of emotion-label words and emotion-laden words: An ERP study. *Frontiers in Human Neuroscience, 11*, 455. https://doi.org/10.3389/fnhum.2017.00455

Zhang, W., Jończyk, R., Wu, Y. J., Lan, Y., Gao, Z., Hu, J., Thierry, G., & Gao, S. (2023). Brain potentials reveal how emotion filters native language access when bilinguals read words in their second language. *Cerebral Cortex, 33*(13), 8783–8791. https://doi.org/10.1093/cercor/bhad161

Appendices

Appendix A. Target stimuli

Table A1. Dutch (L1)–English (L2) word list categorized by Word Valence (negative, neutral, and positive).

Negative		Neutral		Positive	
Dutch	English	Dutch	English	Dutch	English
aartsvijand	nemesis	bedrag	amount	bescherming	protection
afpersing	blackmail	bedrijf	company	bruiloft	wedding
agressie	agression	beer	bear	chocola	chocolate
begrafenis	funeral	behandeling	treatment	dame	lady
beul	executioner	beroep	profession	dans	dance
bloedbad	bloodbath	beschrijving	description	droom	dream
bomaanslag	bombing	bezit	posession	ervaring	experience
catastrofe	catastrophe	brug	bridge	feest	party
crimineel	criminal	deur	door	geld	money
depressie	depression	duiker	diver	gerechtigheid	justice
doder	killer	duim	thumb	gezondheid	health
doodsangst	terrified	eeuw	century	goud	gold
doodskist	coffin	frequentie	frequency	grapje	joke
dreiging	threat	gebouw	building	hart	heart
eenzaamheid	loneliness	geit	goat	hemel	heaven
fraude	fraud	geschiedenis	history	huwelijk	marriage
geweld	violence	gewoonte	habit	idee	idea
gijzelaar	hostage	gezag	authority	kerst	christmas
gijzeling	kidnapping	havermout	oatmeal	kind	child
gruweldaad	atrocity	helm	helmet	kus	kiss
haat	hate	horloge	watch	lach	smile
hongersnood	starvation	invloed	influence	leven	life
inbraak	burglary	jas	jacket	liefde	love
kwelling	torment	knoflook	garlic	magie	magic
lijk	corpse	mentaliteit	mentality	mama	mom
marteling	torture	methode	method	muziek	music
misbruik	abuse	motief	motive	overwinning	victory
miserie	misery	nier	kidney	plezier	pleasure
miskraam	miscarriage	ober	waiter	prinses	princess
moord	homicide	oorsprong	origin	reis	trip
moordenaar	murderer	oorzaak	cause	relatie	relationship
moordpartij	massacre	plicht	duty	roos	rose
ontploffing	explosion	potlood	pencil	schat	treasure
oorlog	war	spiegel	mirror	schoonheid	beauty
overspel	adultery	standbeeld	statue	slaap	sleep
overval	robbery	steen	stone	steun	support
racisme	racism	stemming	mood	strand	beach
slachtpartij	slaughter	tandpasta	toothpaste	vakantie	holiday
terreur	terror	theorie	theory	veiligheid	protection
terrorisme	terrorism	toestand	condition	verjaardag	birthday
tirannie	tyranny	toren	tower	verstand	mind

uitbuiting	exploitation	vaatwasser	dishwasher	voordeel	advantage
verkrachter	rapist	vergelijking	comparison	vrede	peace
verkrachting	rape	verleden	past	vriendin	girlfriend
vijandschap	hostility	verschil	difference	vrijheid	freedom
woede	rage	versie	version	wens	wish
wraakactie	revenge	vrijgezel	bachelor	zee	sea
zelfmoord	suicide	wachtwoord	password	zon	sun

Note: yellow marked words are non-identical cognates between Dutch and English

Appendix B. (Generalized) linear mixed-effects models

Table B1. Results of the generalized linear mixed-effects model for accuracy.

Effect	Estimate	SE	*z*-value	*p*-value
Intercept	2.59	0.14	19.10	<.001***
$Valence_{Neutral\ vs.\ Emotional}$	-1.00	0.19	-5.31	<.001***
$Valence_{Negative\ vs.\ Positive}$	2.23	0.25	8.78	<.001***
$Language_{English}$	-0.44	-1.71	-1.71	.087
$Valence_{Neutral\ vs.\ Emotional}$ X $Language_{English}$	-0.13	0.37	-0.37	.716
$Valence_{Negative\ vs.\ Positive}$ X $Language_{English}$	-2.25	0.50	-4.51	<.001***

Table B2. Results of the linear mixed-effects model for response times.

Effect	Estimate	SE	*z*-value	*p*-value
Intercept	1262.58	31.44	40.16	<.001***
$Valence_{Neutral\ vs.\ Emotional}$	203.82	16.62	12.62	<.001***
$Valence_{Negative\ vs.\ Positive}$	-49.14	19.08	-2.58	.010*
$Language_{English}$	-27.98	62.88	-0.45	.659
$Valence_{Neutral\ vs.\ Emotional}$ X $Language_{English}$	58.99	33.24	1.77	.077
$Valence_{Negative\ vs.\ Positive}$ X $Language_{English}$	124.10	38.16	3.25	<.01**

Table B3. Results of the linear mixed-effects model for the Late Positive Complex.

Effect	Estimate	SE	*t*-value	*p*-value
Intercept	-0.79	0.31	-2.48	.017*
$Valence_{Neutral\ vs.\ Emotional}$	-0.61	0.19	-3.17	<.001***
$Valence_{Negative\ vs.\ Positive}$	0.52	0.22	2.35	.020*
$Language_{English}$	-0.84	0.61	-1.37	0.180
$Valence_{Neutral\ vs.\ Emotional}$ X $Language_{English}$	0.29	0.15	1.97	.049*
$Valence_{Negative\ vs.\ Positive}$ X $Language_{English}$	-0.43	0.17	-2.54	.011*