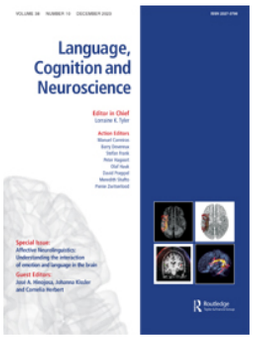

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INTRODUCTION

Introduction to the special issue: Affective neurolinguistics: understanding the interaction of emotion and language in the brain

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ABSTRACT

Emotions permeate every aspect of our lives including how we process and use language. Affective neurolinguistics is an emerging field that aims to unify separate research traditions in neurolinguistics and affective neuroscience. This special issue provides an overview of recent developments, on the lexico-semantic, syntactic and pragmatic levels. The 11 studies address the embodied acquisition of emotional concepts, their network representation in the brain, their representation in the first versus second language as well as the role of attentional focus. They also specify how emotional content interacts with morphosyntactic processing, how inter individual differences determine the primacy of syntax or affect in sentence processing, and how emotional influences play out in the multi-modal integration of language in quasi-realistic communicative settings. In total, this collection of studies covers the status of the field of affective neurolinguistics, laying the groundwork for a more formal multi-level integration of affect into language models.

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Introduction

Language is a privileged means of communication and social interaction. As such, it can also convey emotions of a sender to a receiver and vice versa with little effort and high temporal precision. From the strong affective connotations of single words such as insults or compliments to the more elaborate propositional structures carried by phrases, sentences, or stories, emotional language permeates all aspects of our daily life. Language plays an important role in emotion perception as well as in regulating complex feelings or social interactions.

Traditionally, due to an unfortunate lack of interdisciplinary communication, researchers from the language and affective sciences have largely ignored each other. Thus, neurobiological studies investigating the interplay between language and emotion have been rare. The studies that did (e.g. Bernat et al., 2001; Chapman et al., 1980; Naumann et al., 1997; Ortigue et al., 2004; Schapkin et al., 2000; Skrandies, 1998; Skrandies & Chiu, 2003; see Kissler et al., 2006, for a review of these pioneering studies), already provided evidence for early emotion effects, driven by valence or arousal as the two major core dimensions of emotions proposed by dimensional theories of emotions that also characterise the connotative meaning of words according to the semantic differential technique (Osgood et al., 1957).

Since then, especially the two last decades have seen a quantitative and qualitative leap towards identifying the neurobiological markers of the interplay between language and emotion by investigating the processing of emotional words, phrases or sentences, presented alone or within a broader experimental and social context (for an overview see e.g. Herbert, 2020; Herbert et al., 2018; and Hinojosa et al., 2020b; Kissler, 2013). Based on an idea that was originally conceived in the 55th Annual Meeting of the Society for Psychophysiological Research held in 2015, the term affective neurolinguistics (Hinojosa et al., 2020a; Kissler, 2020) has emerged to bring together researchers from various areas of psychology, linguistics, and neuroscience in an attempt to specify the role of language in emotion and of emotion in language, both theoretically and methodologically (e.g. Herbert, 2015: see Kissler, 2015). Crucially, the aim of this scientific endeavour of affective neurolinguistics is to withdraw from seeing language and emotions as opposing entities and instead elucidate the neurobiological principles of

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language and emotion in their interaction. This accords with a wider movement within neuroscience of language that indicates that language activates not only typical language regions in the brain but also brain regions involved in perception, emotion and action suggesting that language processing is no isolated amodal phenomenon, but embodied and entwined with other cognitive faculties (e.g. Kiefer & Pulvermüller, 2012; Moseley et al., 2015).

Specific progress has been made in investigating the neural correlates of emotional language processing and theorising about potential interfaces and interaction mechanisms in the brain and the body. Accordingly, research has provided rich information about the brain areas and temporal dynamics underlying some of the processes that are involved in reading or listening to words and sentences varying in emotional content. Several studies using EEG and fMRI methodologies have evidenced that, in general, emotional content can be spontaneously extracted from words (e.g. Herbert et al., 2006, 2008, 2009; Kissler et al., 2007, 2009). Further research also showed that attention and task demands influence the processing of emotional words (e.g. Hinojosa et al., 2010, 2014b; Kuchinke et al., 2005; Schacht & Sommer, 2009; Schindler & Kissler, 2016), or that the affective dimensions of valence (i.e. the hedonic tone of a word referent, ranging from negative/unpleasant to positive pleasant) or arousal (i.e. the degree of activation elicited by a word referent, ranging from calming to exciting) make independent contributions to word processing (e.g. Citron et al., 2014; Hofmann et al., 2009; Recio et al., 2014). Another group of studies have examined the impact of emotional content at different language processing stages. The results of this work revealed modulations during the processing of phonology (e.g. Aryani et al., 2019; Ullrich et al., 2016), orthography (e.g. Ding et al., 2015), morphosyntax (e.g. Fraga et al., 2021; Hinojosa et al., 2014a), or lexico-semantics (Kanske & Kotz, 2007; Kissler & Herbert, 2013; Palazova et al., 2011).

Importantly, the scope within the field of affective neurolinguistics has quickly expanded to refine a variety of further aspects about the relationship between language and emotion. Progress has been made in several important directions, such as the neurobiological markers reflecting the representation of different emotional vocabularies (Pavlenko, 2008) like emotion-label words (i.e. words that express feelings or affective states; e.g. *scared*, *satisfied*), or emotion-laden words (i.e. words that have an acquired or indirect affective connotation) (e.g. *knife*, *money*) (e.g. Wang et al., 2019; Zhang et al., 2017), the processing of emotional aspects in non-native language (e.g. Conrad et al., 2011; Wu et al., 2020), or the impact of emotional mood (i.e. transient affective states) on language processing (e.g. Chwilla et al., 2011; Hinojosa et al., 2017; Kissler & Bromberek-Dyzman, 2021; Ogawa & Nittono, 2019). Moreover, the role of emotion in language understanding across development (Sylvester et al., 2021a, 2021b; Yeh et al., 2023), the contribution of emotional features to figurative language (Citron et al., 2016; Citron & Goldberg, 2014), or the pragmatic aspects related to the communicative functions of emotional language (e.g. Aguado et al., 2019; Rohr & Rahman, 2015; Schindler et al., 2015; Schindler & Kissler, 2016) have been addressed. The latter includes the study of the neural and bodily interactions between self-reference, social relevance and emotion processing when conveyed by linguistic content and the impact of this on emotion perception and emotion regulation of non-verbal salient stimuli (e.g. Fields & Kuperberg, 2016; Herbert et al., 2011a, 2011b, 2013a, 2013b). Furthermore, the impact of individual differences in the processing of affective language (e.g. Fraga et al., 2021), the effects of emotional contexts (either words, sentences or texts) on the processing of subsequent neutral words (e.g. Delaney-Busch & Kuperberg, 2013; Ding et al., 2015; Moreno & Vázquez, 2011), or in comparing the distinctive features of the processing of emotional words relative to the processing of non-linguistic emotional stimuli like pictures or faces (Bayer & Schacht, 2014; Hinojosa et al., 2009) (see, Herbert, 2020; Hinojosa et al., 2020b; Kissler, 2020; van Berkum, 2020, for an overview) have all been addressed.

The current issue

With this special issue, we aim to exemplify and structure the diversity of topics that are currently being investigated under the umbrella of affective neurolinguistics. In particular, we aim to enhance our knowledge of the neurobiological bases of the relationship between language and emotion in an attempt to aggregate the next wave of significant contributions to the developing field of affective neurolinguistics. The contributions to this special issue primarily employ highly time-resolved EEG methods, partly combined with anatomic information derived from source localisation or lesion mapping. They cover a broad range of topics from the effects of emotional dimensions and discrete emotions in the processing of individual words and pseudowords (Gibbons et al., 2022; Gu et al., 2022; Herbert, 2022; Kissler et al., 2023; Liu et al. 2022), to the sentence-level emotional modulations of morphosyntactic aspects associated with the computation of person (Poch et al., 2022) or gender (Padrón et al., 2023)

agreement or communicative context effects on the processing of emotional and non-emotional (Aristei et al., 2022; Hernández-Gutiérrez et al., 2022; Maquate et al., 2022) language, extending the scope to the pragmatic role of emotional language. Finally, a theory paper considers factors influencing the embodiment of emotional concepts (Winkielman et al., 2023).

Word level

A first group of articles addresses different aspects of the processing of individual lexical items. In the study by Gu et al. (2022) the authors explore associative learning mechanisms underlying the acquisition of emotional connotations. They found that pseudowords that were previously paired with faces expressing disgust elicited enhanced activation in the insula whereas pseudowords previously matched with faces conveying sadness showed more activation in orbito-frontal and temporal cortices. Processing differences between pseudowords paired with sad and disgust faces were observed about 200 ms, as indexed by amplitude modulations in an Early Posterior Negativity (EPN). These results directly demonstrate the acquisition of novel emotional words on the level of distinct emotional categories (disgust or sadness). In addition to their relevance for the representation of words conveying different emotions, these data provide some insights about how emotional faces, objects or events map onto their lexical labels and could suggest a role for embodiment in this process. This issue might be of particular interest when investigating the acquisition of emotional vocabularies in children (e.g. Grosse et al., 2021; Sabater et al., 2023), or in learning a second language (Pasfield-Neofitou et al., 2015; Sheikh & Titone, 2016).

In an effort to delineate the brain structures that critically contribute to the processing of negative words, Kissler et al. (2023) investigate the impact of left and right anteromedial temporal lobe resections (including amygdala and temporal pole) on reading negative and neutral words in one's native language. While right hemisphere resections selectively abolish P1 responses to negative words, left hemisphere resections reduce centro-parietal positivities from the P2 onwards. Thereby, the results of this study support and specify an important role of the anterior temporal lobe in processing both semantics and emotion (Hung et al., 2020; Lindquist, 2017). Nonetheless, a considerable amount of residual emotion processing was found following both left and right hemisphere resections, indicating that negative words are represented in distributed neural networks that facilitate compensation of unilateral loss of even key embodiment and semantic brain regions such as the amygdala (Buccino et al., 2016) and anterior temporal lobe (Meyer et al., 2010; Tong et al., 2022).

Herbert (2022) sheds light on the specificity of early emotion effects. The study asked if early modulation occurs specifically for emotional content or for other salient body shape, -weight or body part related content as well. The latter contents may acquire emotionality from their embodied socio-cultural sharing, subjective experiences or affective appraisals in relation to their usage in the context of the L1 or the L2; L1 being the native language vs. L2 being the proficient foreign language of the participants. The results suggest a complex interaction between the emotionality of the word, the language (L1 and L2), and the hemispheric lateralisation in early time windows, that facilitates the processing of emotional and body weight/shape related words in the L1 and the L2, but for concrete body words in the L1 only. The observations support and extend previous findings showing no L2 detachment effects for emotional content (e.g. Conrad et al., 2011; Kissler & Bromberek-Dyzman, 2021; Opitz & Degner, 2012). Furthermore, the results indicate the role of emotional appraisals that emerge in the time windows in which lexico-semantic access occurs, and add to an ongoing theoretical discussion of whether early processing effects are subject to embodied lexico-semantic processing (e.g. see also in this issue Winkielman et al., 2023).

The study by Liu et al. (2023) shows how task demands modulate the processing of words that directly denote affective states (i.e. emotion-label words) versus those that convey emotions indirectly (i.e. emotion-laden words). The authors observed that access to more complex conceptual information that does not directly convey affective meaning engaged additional processing resources from 170 to 340 ms, as evidenced by enhanced amplitudes in the P2 and the EPN components to emotion-laden words relative to emotion-label words. In contrast, the processing of emotion-label words elicited greater conflict between their emotional content and other sources of information (i.e. colour in the Stroop task), as indicated by larger N400 and Late Positive Component responses between 300 and 550 ms that were differentially modulated by implicit and explicit processing requirements associated with a Stroop and an emotional categorisation tasks. The results of this study extend the claims made by current models of emotional word processing (e.g. the three-stage model by Zhang et al., 2014) by showing the need of considering the effects of task demands, and the type of emotional vocabulary, particularly during the second (i.e. emotional vs non-emotional

discrimination) and third (i.e. differentiation between negative and positive words) processing stages.

Gibbons et al. (2022) tested the predictions made by the model of the evaluative space (Cacioppo et al., 1997), which assumes a motivational conception of emotion that links positive and negative stimuli with avoidance and approach action tendencies, respectively. This view argues that human beings are prepared by evolution to form associations between negative stimuli and high arousal, whereas positive stimuli would be more easily matched with low arousal. Using a valence detection task in which participants had to identify words that matched the target valence of a particular block of stimuli (i.e. positive words in a positive block), Gibbons et al. (2022) observed context-specific biases in the processing of emotional words that were congruent with the attentional set. They found modulations in several ERP components between 150 and 250 ms, such as the N170 or the EPN, indicating that positive words were easier to processes when the context created a target template involving both positive valence and low arousal, whereas negative words were more easily identified when the context was negative and highly arousing. Overall, these results extend some of the claims made by the theoretical view developed by Cacioppo et al. (1997) by highlighting the relevance of the linguistic emotional context and the attentional set when processing affective stimuli.

Sentence level

Moving from the processing of individual words to the sentence level, two studies addressed the influence of the emotional features of words on morphosyntactic aspects related to the processing of agreement dependencies between sentence constituents. In the first of these studies, Poch et al. (2022) found that feature-checking operations dealing with the early detection of person agreement mismatches (e.g. "I_{1st} *sing*$_{2nd}$ in the shower") are less efficiently detected when they occur in either positive or negative sentences relative to neutral sentences, as evidenced by modulations in the amplitude of a Left Anterior Negativity (LAN) around 400 ms. This finding is in line with lexicalist views which assume that the computation of agreement dependencies relies on several sources of information extending from structural features to conceptual elements (e.g. Wagers et al., 2009). It establishes emotional content as one such conceptual element.

Padrón et al. (2023) went one step further by demonstrating individual differences in the interplay of affect and sentence-level morphosyntax. They showed that the processing of gender agreement violations in positive words embedded in noun phrases (e.g. "The astute$_{fem}$ lawyer$_{masc}$") is mediated by individual differences in the pattern of brain activity. Accordingly, participants who show a pattern of brain activity characterised by a preponderance of the early mismatch detection mechanism (indexed by LAN activity around 350 ms) prioritise the processing of grammaticality over affective cues. In contrast, individuals who rely more heavily on brain mechanism associated with late detection of agreement violations that reflect the cost of the repair and revision of this type of errors (as evidenced in P600 amplitude modulations around 650 ms) give precedence to the processing of emotion over grammatical features. All in all, the results of these studies underscore the need of incorporating the contribution of emotional information and inter-invidual variability into neurobiological models of sentence parsing (e.g. Bornkessel-Schlesewsky & Schlesewsky, 2013; Friederici, 2011; Hagoort & Indefrey, 2014).

Several studies in this special issues have added a more complex multimodal and pragmatic twist to investigate the influence of the affective aspects of communicative settings in sentence processing.

The study by Hernández-Gutierrez et al. (2022) deals with emotional context effects in language understanding. These authors simulated a face-to-face communicative setting in which participants listened to non-emotional sentences while viewing a picture of the speaker's face that could depict either a fearful, a happy, or a neutral expression. The finding of an enhanced P600 amplitude around 550 ms suggests a prioritised reanalysis of the grammatical structure in sentences that included gender (e.g. "The *embroidered*$_{Fem/Sing}$ cushion$_{Masc/Sing}$ belonged to my grandmother") and number (e.g. "The tourists had photographed the$_{Masc/Plur}$ arctic *glacier*$_{Masc/Sing}$") agreement mismatches when the face of the speaker expressed happiness relative to fearful or neutral expressions. The authors speculated that happy faces may boost a less demanding processing style that strongly relies on the use of heuristic strategies to understand language.

Whereas Hernández-Gutiérrez examined the effects of the speaker's facial expression on the processing of neutral-valenced language while sentences were presented simultaneously, Maquate et al. (2022) focused on the effects of happy and sad speakers' faces on the processing of a subsequent auditory sentence description of a simultaneously presented emotional picture. Across two experiments, it was found that sentences describing negative images were more difficult to process when preceded by a picture of the speaker's face displaying happiness between 250 and 600 ms as indexed by amplitude changes in the EPN and N400

waves. Interestingly, these effects were only observed in female participants, which is in line with prior observations of gender biases in the comprehension and production of emotional language (e.g. Naranowicz et al., 2023). The findings by Hernandez-Gutiérrez et al. (2022), and Maquate et al. (2022) suggest that the emotional expression depicted in the face of our interlocutors is taken into account when processing language.

Of note, whereas Hernández-Gutierrez et al. (2022) did find effects on morphosyntactic processing, they failed to observe social-context modulations in the processing of semantically or conceptually incongruent sentences (e.g. "The *roasted* cushion belonged to my grandmother") by the facial affective expression of the speaker. In contrast, Aristei et al. (2022) reported affective contexts effects during the processing of conceptual features. In this sense, the authors showed that negative contexts represented by short passages reduce the depth of semantic analyses of core knowledge violations in the form of counterintuitive concepts (e.g. "The barren willow tree *talks* to the girl"), as reflected in modulations of the N400. This finding is in agreement with prior observations indicating that contexts with a negative valence facilitates the access to semantic information in forthcoming emotionally congruent words and attenuates the processing of neutral words (Delaney-Busch & Kuperberg, 2013). The authors also warn of the possibility that this reduction in critical conceptual processing could be taken into account when generating illogical or contradictory statements in order to manipulate the veracity of messages, such as in political discourses or in the generation of fake news.

Overall, the results of these three studies have implications for recent theoretical developments and accumulating experimental evidence that points to the need of considering the "situatedness", that is the contextual cues and the affective characteristics of language users, both speakers and comprehenders, when addressing research questions dealing with the processing of language (Münster & Knoeferle, 2018; van Berkum, 2019, 2020). A similar point is made in the theoretical proposal by Winkielman et al. (2023) which is inspired by a grounded cognition approach to emotional language (Barsalou, 2020; Kiefer & Barsalou, 2013). In this vein, they propose a multiple representation account of the construction of emotional meaning, which they call CODES ("The Context Dependent Nature of Embodied Emotion Concepts"). This view not only assumes the importance of somatosensory and interoceptive information in the processing of emotional words (in line with prior observations, e.g. Ferré et al., 2023; Kragel & LaBar, 2016), but also emphasises the need of taking into account individual goals and resources. According to the authors, the contribution of all these different components is shaped by situated contexts and linguistic interactions which are constrained by cultural variation (Lindquist et al., 2022). Importantly, Winkielman et al. (2023) argue that emotion concepts might involve activations in a hierarchically organised network of cortical representations from regions with varying degrees of modal representation to supramodal or amodal regions.

Conclusions

Through the use of different experimental approaches, the articles in this special issue provide insights into a variety of topics of relevance to the identification of the neural and cognitive underpinnings of the interplay between language and emotion: that is from lexico-semantics on the single word but also the sentence level, to morphosyntax, or pragmatic aspects related to communicative settings. What is more, the results from these studies highlight the need to take into account issues like the role of associative learning mechanisms in acquiring the meaning of emotional language, dissociations between emotional effects in the first and second languages, the roles of participants' goals and tasks and the existence of inter-individual differences, when addressing the neurobiological markers of emotional language.

A major challenge for the field of affective neurolinguistics is to determine how these observations can be instantiated in current neurobiological models of language. Conversely, new theoretical developments in affective sciences should take into account the symbolic nature and the special characteristics of language when it is used to convey emotions in comparison with other types of emotional stimuli like pictures or images. The research covered in this special issue hopes to inform such integrative models and, with its focus on EEG studies, could provide particularly useful information regarding the temporal aspect of processing. Recently, some tender shoots have blossomed into theories that have borrowed some ideas from psycholinguistics and the pragmatic analysis of communications to highlight the key role of emotion in computing lexical representations of the world to understand and generate language (e.g. affective language comprehension model, van Berkum, 2019, 2020). Others have hypothesised that emotions are abstract conceptual entities which emerge from both implicit categorisation processes and linguistic labelling (e.g. constructivist theories of emotions, Barret et al., 2007; Lindquist, 2013). This special issue aims at providing fertiliser for a

systematic growth of these kinds of approaches. Let's keep watering them.

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