Affective language processing:

Modulations of event-related potentials amplitude by induced mood in a valence judgment task

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Abstract

Emotional vocabulary enjoys a processing advantage, with the emotional salience of a word detected at 200 ms post-presentation or earlier, signalling selective attention to its affective properties. An individual's affective state also impacts attention and, by extension, affects processing. This study investigates whether and how preferential processing of emotional valence is modulated by mood. Participants performed an evaluative decision task in L1 judging the valence of individually presented words in a control mood and two mood-induced conditions. Recorded event-related potentials (ERPs) were analysed in the time window of the early posterior negativity (EPN) and the late positive complex (LPC) to cover both early lexical-semantic access and more elaborate and motivated semantic processing. Mood was only found to significantly modulate affective language processing at the later stage. Mood-induced alterations of the ERPs did not follow a mood-congruent pattern: negative words elicited consistently higher amplitudes across conditions and sustained little effect of mood changes, while reactions to positive words were modulated by mood. The results are discussed against the background of associative network theory and differential attentional effects of mood.

Keywords: affective processing, emotion, ERP, lexico-semantic processing, mood, valence

Table of contents

List of abbreviations

ANEW	Affective Norms for English Words
DASS-21	Depression Anxiety Stress Scales
EEG	electroencephalography
EPN	early posterior negativity
ERP	event-related potential
fMRI	functional magnetic resonance imaging
HEO	horizontal electrooculogram
ICA	independent component analysis
IAPS	International Affective Picture System
ISI	inter-stimulus interval
ITI	inter-trial interval
L1	first language
L2	second language
LEAP-Q	Language Experience and Proficiency Questionnaire
LPC	late positive complex
MIP	mood-induction procedure
PANAS	Positive and Negative Affect Schedule
RM ANOVA	repeated-measures analysis of variance
ROI	region of interest
RT	reaction time
SAM	Self-Assessment Manikins
SOA	stimulus-onset asynchrony
VEO	vertical electrooculogram

List of figures

List of tables

Acknowledgments

About a year ago I heard about the case of Elliot, a patient of Antonio Damasio's, who sustained surgery on his prefrontal medial cortex, which utterly undermined his ability to make decisions. It made everything fall into place: you cannot make decisions if you withdraw from your emotions. No amount of rationalisation can be a remedy for soothing an emotional pain if you have lost contact with it. The second thought was that it is all in the brain: you may not know but the brain knows. That kind reminder helped me recall why I found myself in Lund.

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1. Introduction

Feelings: oh, I have those; they govern me.

–Louise Glück. The Red Poppy

Emotions are part of our daily life, and we express them continuously through language. Conceptualisation of emotional experience, its encoding and retrieval has been a subject of affective neuroscience, psycho- and neurolinguistic research (e.g., Klauer & Musch, 2003; Kotz & Paulmann, 2011; Lindquist et al., 2012). The emerging field of affective neurolinguistics integrates research at the intersection of emotion, language and the brain (Hinojosa et al., 2020). By combining the robust exploration of language processing that neurolinguistics can do with the processing of emotion seen in the theoretical framework of affective neuroscience, the field investigates the neural pathways of emotional expression through language. Evidence accumulated in these fields points at a prioritised processing of emotional features of language over other semantic information. Emotional units across language levels are selected from the array of incoming information and are processed faster, remembered better and recalled more easily.

The processing advantage of emotional language is attributed to an automatic allocation of attention to emotional stimuli in general and a vast network of neural connections that emotional words activate. Affective semantics of a word are described in terms of valence and arousal, where valence denotes the degree of pleasantness of the word and arousal indicates how strong the emotional component is. This way, the word '*home'* is described as high in valence and moderate in arousal, while '*pain'* ranks low in valence and high in arousal (based on ratings from Bradley & Lang, 2017). Access to these properties does not occur simultaneously, with arousal being the first indicator of emotiveness in a word. Although the allocation of attention to an emotional word occurs automatically, labelling it as pleasant or unpleasant requires more effort and takes place when lexical-semantic representations are being accessed (e.g., Citron, 2012).

In affective neurolinguistics, one of the main questions is the relationship between emotional content of words and processing stages: research aims to determine whether emotional features are accessed in parallel with the analysis of the visual form, or during later access to semantic representation (Hinojosa et al., 2020; Kotz & Paulmann, 2011). This study expands this question to include mood as an affective context and investigates how mood influences emotional language processing.

Mood, or a prolonged affective state, is a property of the reader or listener and thus part of the communicative context which influences the decoding of verbal stimuli (van Berkum, 2018). Both moods and emotional words can be described in terms of their valence, begging the question of a possible facilitation in the case of congruence of an emotional word with mood. A positive mood appears to be a better facilitator than a negative mood, which indicates that the degree of pleasantness alone is not the only factor that contributes to facilitation or inhibition (Schwarz, 2012). Moods also modulate memory and attention processes, which play a part during linguistic decoding and may therefore indirectly influence the perception of emotional features of words (Forgas, 2002; Schwarz, 2012).

While emotional language processing has been in the limelight for decades, the study of moods and their effects on linguistic processing is only gaining momentum. Studies of the interaction between mood and emotional valence are few, and they fail to reveal a consistent pattern of interaction between the two. Earlier behavioural studies found a linear interaction between mood and valence, where mood inevitably facilitates processing of congruent emotional words, as would be suggested by associated network theories (review in Sereno et al., 2015). That being said, recent studies fail to replicate those findings, and an emerging pool of electroencephalographic (EEG) data also indicates that there are other factors at play, like attention allocation and the different processing strategies adopted in different moods (e.g., Kiefer et al., 2007; Kissler & Bromberek-Dyzman, 2021; Pratt & Kelly, 2008).

This study aims to contribute to the growing array of studies on mood and valence interaction by investigating how valence effects unravel in time in different mood conditions during written language processing. It answers the following questions:

RQ1: Does mood modulate the processing of emotional valence of words?

RQ2: Do mood effects on valence manifest themselves across the earlier and later stages of word processing?

RQ3: Are modulations of emotional valence mood-congruent?

The affective component of word semantics is accessed automatically and rapidly, meaning that following lexical-semantic processing online is essential to understand the way affective meaning is activated and how it is possibly enhanced or inhibited by a global emotional context. The method of EEG makes it possible to track the activation of neural networks in real time from the earlier stages of the stimulus recognition to the later stages of contextual integration. Research of the way stimuli are perceived in time in different mood conditions is achieved through mood induction procedures, where participants' affective state is manipulated by means of exposing them to emotional images, film or music (Joseph et al., 2020; Westermann et al., 1996).

The thesis consists of five chapters. The introduction into the topic is followed by a presentation of the theoretical foundation in *Chapter 2*. Its two sections explain the key notions of emotion and mood, summarise existing theories, explore neural correlates of emotional words and prolonged affective states and give an overview of existing studies in the domains of emotional language and mood studies. Hypotheses are formulated at the end of the chapter. *Chapter 3* gives an overview of the method; it speaks about stimuli sorting for the mood induction and evaluation parts of the experiment, and explains the way the data was statistically handled. *Chapter 4* presents the results of the mood induction procedure, behavioural and electrophysiological parts of the study. *Chapter 5* revisits the research questions and hypotheses and discusses the results.

2. Theoretical background

2.1 Affective processing

From the point of view of language processing, emotional words occupy a not yet well-defined niche. They possess both some degree of abstraction and concreteness, but are not fully reducible to either of these categories (Kemmerer, 2014, p. 351). They span across grammatical categories. It appears that it is the emotional component embedded in them is what makes them stand out. This section explores the theories explaining the processing advantage of emotional words. These explanations are rooted in different physiological motivations (like the urge to approach or withdraw), attention, and in the difference in the neural pathways of emotional words (Kissler et al., 2009; Kotz & Paulmann, 2011; Lang et al., 1997; Wilson-Mendenhall et al., 2011). Neurolinguistic research in visual affective processing is further summarised.

A clarification of the use of emotion-related terminology in this thesis is to be made at this point. This study looks at all words containing an affective component, be they emotion labels, like '*sadness'*, or emotionally laden words, like '*beauty'*. *Affect* is used to describe the basic underlying combination of arousal and valence (Russell, 1980; Satpute & Lindquist, 2021), before those are assessed in context and labelled by any particular word. *Emotion* refers to a type of feeling[1] that is experienced as a result of the affect in a particular context by a particular individual. Affect is a component of emotion, but is not reducible to it (Lindquist et al., 2012; Moors & Scherer, 2013). A *prolonged affective state* denotes episodes of experiencing an emotion over a longer time period with less intensity and is synonymous to *mood* (Frijda, 2009; Hajcak et al., 2012). Finally, *affective processing* is used to denote the processing of emotional valence and arousal (affect), as opposed to semantic processing, which here stands for accessing lexical-semantic representations of words – their referential meaning (Hinojosa et al., 2020; Satpute & Lindquist, 2021). This distinction is made to

[1] Here, emotion and feeling are used interchangeably, although they are regarded as physiologically different notions in some theories. For example, Damasio (1996) argues that emotions are a set of somatovisceral reactions (ones taking place in the body muscles and bloodstream) that lead to a response to a stimulus. Feelings are neural reflections of emotions; these are representations in the brain of the reactions elsewhere in the body. In this paper, for the sake of convenience, and because the study only looks at neural responses, no difference is made between the two terms.

differentiate between the recognition of the emotional salience of a word, which takes place earlier, and retrieval of lexical meaning, which follows separate neural pathways and occurs in parallel or later.

2.1.1 Processing advantage of emotional language

The processing advantage of emotional words over neutral ones manifests itself in a greater processing speed, better memorisation and faster recall (e.g., Kotz & Paulmann, 2011). They activate a vast network of neural connections, which include both cortical and subcortical structures. In addition to the language areas, emotional words engage regions responsible for the processing of emotions. Among others, these include the amygdala, which is part of the limbic system and therefore initiates a rapid automatic reaction to an irritating stimulus, the hippocampus, which is responsible for short-term memory, and the anterior cingulate and prefrontal cortices, which modulate attention processes (e.g., Abbassi et al., 2011). Such neural architecture is consistent with the Grounded Cognition model (Barsalou, 2008), according to which words do not only activate the areas of the brain where semantic representations are stored, but also the dominant sensorimotor regions. This way, similar to the way action concepts trigger action-related brain regions (e.g., Pulvermüller et al., 2005), emotional words stimulate areas responsible for the perception, construction and regulation of affect.

Activation of attention areas presupposes an increase in attention during the processing of emotional words, as is the case with all emotional stimuli. The motivated attention hypothesis (Lang et al., 1997) links this processing advantage to the evolutionary salience of emotional stimuli and posits that they are facilitated through mechanisms of selective attention due to their prototypical relevance for defence and survival. Emotional cues activate one of the two motivation subsystems: appetitive for the positive affect, encouraging approaching and interacting with the stimulus, and defensive for the negative affect, promoting withdrawal. The strength of the emotional response to the stimulus determines the strength of the motivation (ibid).

2.1.2 Two-dimensional view of affect

The emotional component of meaning is typically described following a dimensional view on the structure of affect with the two main axes of *valence* and *arousal* (Russell, 1980, p. 1163), where valence denotes the degree of pleasantness of the affect and points at the tendency to choose one of the two motivational subsystems, and arousal signals its intensity and by extension the strength of the choice. These dimensions do not seem to be completely independent, since covariance between their levels has been found, such that highly negative and / or highly positive stimuli are also ranked high on arousal (e.g., Bradley & Lang, 2017; Lang et al., 2008). Negative stimuli are prioritised in processing due to their potential threat, causing a stronger and faster fixation and a less rapid disengagement (automatic vigilance hypothesis, Pratto & John, 1991).

The two-component approach to the study of affect stems from the dimensional view of meaning as a combination of ratings for individual words on semantic differential Likert scales (Osgood et al., 1957). This method arranges sets of words based on their emotional rather than referential meaning. Word ratings are obtained by asking multiple participants to place a word between two contrasting adjectives, like *pleasant/unpleasant, good/bad, beautiful/ugly*, etc. Averaged ratings give an understanding of the affective value of a word, which does not necessarily correlate with the referential meaning or the degree of abstraction: the words '*beauty'* and '*puppy'* may be equally pleasant. The dimension of valence is present cross-linguistically (Wierzbicka, 1999, Chapter 7), and cross-culturally (Osgood, 1964, p. 199), and both valence and arousal have been used to evaluate affective properties of stimuli across modalities and semiotic systems (Bradley & Lang, 2017; Lang et al., 2008). The fact that the same dimensions are used across cultures and systems underlines a universal character of the dimensions, and points at a shared neural mechanism responding to emotional stimuli. Theories of emotion describe patterns of the interaction between the affective and semantic meaning.

2.1.3 Theories of emotional processing

Different theories of emotion offer different models of the way semantic and affective processing interact when perceiving emotional vocabulary. This relationship can be described in one of four ways, ranging from a deterministic to non-interactive way (Satpute & Lindquist, 2021, p. 214). At one end of the spectrum, as a purely theoretical possibility, the linguistic determinism hypothesis posits that language constructs emotions (e.g., Kay &

Kempton, 1984, in Satpute & Lindquist, 2021). Under basic emotion theories, on the contrary, affective processing is a purely physiological response to the situation; it precedes cognition and is independent of language (e.g., Ekman & Cordaro, 2011, in Satpute & Lindquist, 2021). These theories do not follow the dimensional view of emotion, neglect contextual influences on affective processing, assume that language and emotions follow discrete neural pathways and lack interaction, and will therefore not be discussed in this paper. Less extreme cases of the relation between emotion and cognition presuppose either a constructionist view, where language assists in making sense of emotional reactions, or an interactive approach, where the emotion and language systems are more autonomous, yet affect each other.

Constructionist theories posit a strong connection between semantic processing through verbally labelling an emotion in the process of experiencing emotions themselves (Satpute & Lindquist, 2021, p. 215). They find evidence in studies on patients with brain lesions who have lesions in areas responsible for language processing that also impede their ability to experience emotions (ibid, p. 213). Under these theories, during the affective processing of a stimulus, a sensory array is automatically generated along the dimensions of valence and arousal. The immediate context in which the input was made is also automatically registered. Predictions are then generated by the brain of the meaning of this contextualised affect. These context-sensitive predictions are determined by semantic categorisation, which makes certain features more prominent and others neglected. As a result, the same affective input can be situationally conceptualised as a physiological response, such as a pounding heart, a discrete emotion like fear, or a property of an object, such as the word "*scream*" being unpleasant. Proponents of psychological constructionist theories of emotion hypothesise that brain areas responsive to affect are not specific to any emotional category in particular, and categorisation occurs in the semantic hubs. Emotion concepts determine categorisation, because affective input alone cannot build strong boundaries between categories. Words, instead, are used as "the glue that holds the category together" (Lindquist et al., 2012, p. 125).

According to a more interactive approach, adopted by appraisal theories of emotion, affective and semantic processing activate two distinct, yet interacting systems (Moors et al., 2013). They introduce a special appraisal mechanism which compares the affective input against the individual's values, goals and needs, and sets off affective processing. This triggers the motivational component responsible for the readiness to act and choose the type of action. Changes in endocrine, autonomic, and somatic nervous systems follow. Unlike in constructionist theories, it is only at later processing stages that interpretative processes in the semantic system take place, such as categorisation and attribution of affective valence. The emotion will have already formed, and the attached verbal tag can only adjust the valence and arousal dimensions to a certain extent, for example by describing an event as "*surprising*", "*amazing*" or "*astonishing*".

The debate between these two theoretical frameworks is ongoing, with research in neurolinguistics leaning towards constructionist models. This thesis does not aim at resolving the debate or evaluate the sets of theories. Rather, it is important to emphasise that despite the differences, constructionist and appraisal theories agree on important major points. Firstly, they both share a grounded cognition view of language. Secondly, both take a componential view on emotions, meaning that several components add up to generate an emotion, such as arousal and valence that generate affect, and contextual input that is instrumental for making sense of the affect. Finally, both assume that affective processing undergoes two stages: an automatic, rapid comprehension of an emotional stimulus, and a slow, more conscious evocation of associated concepts.

2.1.4 Stages of emotional language processing

Processing of emotional language undergoes a set of stages (Kotz & Paulmann, 2011, p. 118). In visual language perception, the analysis of sensory features of the word takes place within the first 100 ms post word onset. During this stage, the stimulus is identified as a word, and an analysis of its visual form is performed. Emotional salience of the word is detected during early lexical access, at around 200 ms (ibid, p. 113), although some studies have found that lexical processing may occur even earlier, within the first 200 ms post word onset, which means that lexical properties, including affective ones, might be accessed before or along with the analysis of its spelling (review in Hinojosa et al., 2020, p. 3). Finally, the lexical meaning is retrieved and contextual integration of the word starts at around 400 ms. The latest stage of affective language processing is closely related to attention allocation to the task, and emotional facets of the word will only be continuously registered when attention is directed towards the stimulus.

During earlier processing stages, until 300 ms post-presentation, words are believed to be only differentiated based on arousal. The valence effect manifests itself during later, more controlled stages, between 500 and 800 ms post word onset, where negative words generate a more pronounced response than positive ones (e.g., Hinojosa et al., 2020, p. 4; Kotz & Paulmann, 2011, pp. 113 – 116).

2.1.5 Event-related potentials responsive to emotional content

Electrophysiological research makes it possible to tap into activation patterns generated by specific stimuli in the brain as they unravel in time. Electric potentials that emerge between two electrode sites in response to a stimulus are recorded in real time, and, because they are related to a particular event, are called event-related potentials (ERPs) (Luck, 2014). Recorded without any delay in responses, as is the case with behavioural measures, they allow researchers to study activation across processing stages.

ERPs are analysed in terms of their amplitude and latency. Early emotion-related components are influenced by the physical features of the stimuli, like the font, colour and size of a visually presented word, followed by ERPs that respond to specific features, like their degree of arousal or valence, and more elaborate processing steps, like the build-up of semantic representations. Stimulus evaluation, target identification and other recognition processes are associated with positive ERP components, with slow positive waves modulated by memory-related processes. Slow negative waves may reflect the brain’s higher-order conceptual activity (Cuthbert et al., 2000). Based on the assumption that emotional salience is reliably detected at around 200 ms post word onset (Hinojosa et al., 2020; Kotz & Paulmann, 2011), this section will only focus on the mid- to late latency emotion-related ERPs: the Early Posterior Negativity (EPN) and the Late Positive Complex (LPC).

The EPN is a negative wave between 200 and 300 ms that is most pronounced at occipito-temporal electrode sites. For shorter stimulus durations (about 300 ms), it may present as an absolute negativity; for longer presentation time – as a reduction in positivity (Hajcak et al., 2012, p. 447). It falls into the group of N2 components, and, like all components within the N2 time-window, is a marker of attention processes and signals automatic attention allocation to specific features of a visually presented stimulus, like its emotional nature. While earlier studies qualified this component as task-independent (Kissler et al., 2006), later research found a difference in the EPN amplitude depending on direct attention allocation to the stimulus, when the participant engages in lexico-semantic analysis of the presented word, as in lexical or semantic decision task rather than discrimination during visual processing, for example, in the emotional Stroop paradigm (González-Villar et al., 2014, p. 940).

This component is robust, and has been observed across different word classes and stimulus durations (reviews in Citron, 2012; Hinojosa et al., 2020; Kissler et al., 2006; Kotz & Paulmann, 2011). It is clearly modulated by arousal, as emotional stimuli consistently evoke higher ERPs than neutral ones. In some studies, a valence effect has also been reported, although it is inconsistent, with a higher amplitude for positive than negative words in some studies (Kissler & Bromberek-Dyzman, 2021) and negative higher than positive in others (Imbir et al., 2015; Scott et al., 2009; Wu et al., 2021), which is not in line with the motivated attention and automatic vigilance hypotheses summarised above. Hinojosa et al. (2020) explained the more pronounced role of arousal in the EPN modulations by the fact that there is a greater standard deviation in word ratings of arousal than valence, and the fine-grained differentiation in arousal directs attentional resources to that dimension rather than valence. The valence effect appears to affect early ERPs only when the stimuli are presented in a context that is relevant for the participant (Kissler & Bromberek-Dyzman, 2021).

The LPC is a sustained positive deflection that begins at 350 – 400 ms post-stimulus, peaks at around 800 ms and has a tail of 1.5 s or longer. It has an occipito-parietal distribution, moving to the central zone after 800 ms (Hajcak et al., 2012, p. 449). The LPC indicates a more controlled, higher-order processing during post-sensory stages and points at a relocation of attentional resources at a stimulus, reflecting the activation of motivational systems in the brain (Cuthbert et al., 2000). It is task-dependent, signalling allocation of motivated attention in passive viewing and lexico-semantic tasks (review in Citron, 2012; Hinojosa et al., 2020; Kissler et al., 2006). That being said, in tasks coming with a considerable cognitive load, the response to emotional stimuli may be subdued, which must be considered in experimental design.

It seems to respond acutely to affective stimuli related to key biological motivations, but its amplitude also fluctuates during higher order conceptual activity. Its amplitude is higher for emotional rather than neutral stimuli. Unlike the EPN, the LPC is consistently responsive to valence. However, the polarity of that effect is unclear, with some studies reporting increased amplitudes for negative words (e.g., Kanske & Kotz, 2007; Wu et al., 2021; Zhang et al., 2017), and others – for positive (e.g., Herbert et al., 2008; Kissler et al., 2009).

2.1.6 Topography of emotional language processing

Language is considered to be predominantly left-lateralised, while emotion areas are for the most part located in the right hemisphere (e.g., Kemmerer, 2014). In line with the Grounded Cognition model and both appraisal and constructionist emotion theories, emotional language processing causes activation across both semantic and affective regions, begging the question of lateralisation. In addition to the areas responsive to language in general, such as the left inferior frontal gyrus (BA 44, 45) and the left anterior temporal lobe (e.g., Abbassi et al., 2011, p. 379; Kotz & Paulmann, 2011, pp. 109 – 113), emotion words also activate other areas depending on the processing stage.

In the EPN window, during automatic processing, fMRI data show a consistent activation in the orbitofrontal cortex, which is relevant to reward during decision-making, the mid-fusiform gyrus, which is responsible for word recognition, and the amygdala. Response in the amygdala has been found both for negative and positive words, supporting the role of arousal and emotional salience in general rather than negative emotions in its activation (Abbassi et al., 2011, p. 380). Activation in these areas is mostly left-lateralised (for reviews of fMRI studies of affective language processing, see Abbassi et al., 2011; Citron, 2012; Hinojosa et al., 2020; Kotz & Paulmann, 2011).

During more controlled stages in the LPC window, attention-related structures are activated, namely, the anterior cingulate cortex and the dorsolateral prefrontal cortex (e.g., Duggirala et al., 2022). In an evaluative judgment task of emotion concepts, Lee et al. (2022) found activation in the right anterior medial prefrontal cortex, right ventro-medial prefrontal cortex and midline precuneus. No activation was found in the salience areas responsible for the generation of affect, such as the amygdala or the anterior cingulate cortex. This finding is in line with earlier fMRI studies (review in Abbassi et al., 2011) that also support the hypothesis that semantic information is processed automatically in the left hemisphere, and in a more controlled way in the right hemisphere.

2.1.7 Summary

To recap, the processing of emotional vocabulary activates a vast network of neural connections spanning over brain regions responsible for sensorimotor, affective and language processing, in line with the Grounded Cognition model (Barsalou, 2008). Affective processing of visually presented language undergoes several stages. After the perceptual properties of the presented word have been assessed, its emotional salience is determined. At this stage, emotional words evoke a more prominent response than neutral ones, which is accounted for by the motivated attention hypothesis. These effects are mostly left-lateralised. Emotion-related areas in the right hemisphere start to get engaged at the later, controlled processing stages. During lexico-semantic processing, when the semantic meaning of the word is assessed and contextually embedded, the valence effect appears. Negative words may prompt a greater reaction than positive ones, as predicted by the automatic vigilance hypothesis (Pratto & John, 1991). However, the studies describing the interaction of arousal and valence over time lack consistency, and more research is needed to understand (1) whether valence effect manifests itself during automatic or controlled processing stages, and (2) whether negative or positive words draw more attentional resources. The lateralisation during different stages of emotional word processing is yet another domain to be researched, with seemingly a broader network of neural connections over both hemispheres activated during later processing stages.

2.2 Mood

The processing of linguistic stimuli is dependent on the pragmatic context, and emotional vocabulary is no exception. As stated by the theories of emotion, emotional meaning is generated through contextual integration of affective input. Considering that affect is a combination of valence and arousal, the question arises whether the processing of emotional valence is altered by a context that is itself non-neutral. On the one hand, the effect of valence might be enhanced, meaning that a positive stimulus will be perceived as more positive if the global affective context is positive, too. Yet, this is only a partial description of the predicted effect, and it does not necessarily entail that a negative context will generate inhibitory effects. The relationship between immediate stimulus features and a global state might be less linear. To make more specific predictions about the role of emotional context on the perception of valence, some theoretical issues must be addressed.

Prolonged affective states, or moods, are characterised in terms of how positive or negative they are, which places them on the dimension of valence. Mood is understood as a diffuse affective response that arises as a result of the appraisal of a broader situational context along the dimensions of valence and arousal. In comparison with emotion, it fluctuates more slowly, lasts longer, and is less influenced by particular eliciting stimuli (Frijda, 2009, p. 258; Hajcak et al., 2012, p. 442). Since they are also manifestations of affect, albeit more extended in time and perhaps tuned down, moods are expected to modulate cognition in a similar way to emotions. That being said, research on the interaction of language and mood is relatively limited, and not much has been done yet to understand possible effects of mood on emotional language processing. This section outlines the effects of mood on cognition in general, and on evaluative judgments in particular, and then summarises relevant existing research on the interaction of mood and language.

2.2.1 Mood effects on cognition

Differences in mood cause behavioural and cognitive changes in an individual. Positive mood promotes reward-oriented behaviour, which manifests itself in exploration and engagement with the environment. Negative mood, on the contrary, is aimed at escaping punishment and leads to withdrawal and avoidance tendencies. Processing speed is also affected, with facilitation in a positive mood and processing difficulties in negative. Facilitated perception in a positive mood is linked to the distribution of attentional resources: attention is more dispersed in a positive mood, and more focused in negative (Schwarz, 2012).

These differences can be summed up as distinct information processing styles. Kiefer et al. (2007) explain mood modulations of information processing by the choice of adaptive strategies in different moods. Assimilation, selected in a positive mood, is a form of top-down processing, whereby incoming information is altered so that it fits internal structures of semantic knowledge which are activated in the course of information processing. Negative mood favours the strategy of accommodation, i.e., modifying internal structures so that they fit incoming information, which is changed very little itself. This is a more focused and bottom-up processing style. As a result, positive mood will enhance memorisation, since it is aimed at creative integration of incoming information into existing structures, while negative mood will facilitate retrieval because it is tailored to scan the environment for danger, hence, inherent properties of the stimulus will be more readily retrieved (Kiefer et al., 2007, pp. 1516 – 1517).

2.2.2 Effects of mood on affective judgment

The mood effects on cognition described above may be left unnoticed by the individual, affecting their decision-making and skewing judgments which are inherently made under the influence of the affective state (Damasio, 1995, pp. 243 – 244). The Affect-as-Information hypothesis (Schwarz, 2012) proposes that a pre-existing emotional state, which is not directed at anything in particular, may be mistaken for a reaction to an individual stimulus, and thus become an unaccounted-for factor in decision-making, causing the valence of the mood to expand to the evaluation of the object. Interestingly, in a study of momentary moods on general well-being judgments (Schwarz & Clore, 1983), people were shown to rarely link their bad mood to low levels of life satisfaction, while happy moods were stated as a foundation for feeling happy overall. This finding speaks about mood asymmetry and goes to show that people are more consciously aware of their positive mood and there is a higher degree of detail-orientation in negative moods. This theory posits that mood has a strong leverage in decision-making and neglects the factor of the inherent properties of the object as it is evaluated. Effects of mood on memory and associations are also beyond the scope of this model.

Interaction between mood and the affective features of a stimulus can be explored through associative network models. The spreading activation model (Collins & Loftus, 1975) posits that semantic concepts are stored as nodes integrated into a semantic conceptual network. Nodes connecting words of associated semantic categories have stronger neural connections than non-related words. The neural connections are strengthened by the frequency of use between associated nodes. Once a node is activated, activation will also spread across the network to semantically related words. On this foundation, Bower (1981) explained congruence effects of non-neutral vocabulary in memory, attention and semantic judgments. Similar to words, affect generates cognitive representation networks. Associated memories and ideas are automatically primed by an induced affect, facilitating access to them. Inherent affective properties of the stimulus are in no way modulated by the mood: positive stimuli are perceived as positive irrespective of which mood the recipient is in. Rather, stimuli with a congruent affective profile are prioritised. Bower's theory is supported by the Somatic Marker hypothesis (Damasio, 1995), according to which the process of recollecting an emotional event causes an activation of somatic markers associated with that memory.

The priming mechanism is seen as ubiquitous and disregards the possibly different processing styles in different moods, as well as the properties of the task. Bower's theory can account for affective priming (e.g., Klauer & Musch, 2003), yet it is not supported by experimental data obtained in designs with a greater difference in time between the start of one stimulus and the start of the next one (SOA, stimulus onset asynchrony) (e.g., Kiefer et al., 2007; Pratt & Kelly, 2008; Sereno et al., 2015). This may be due to the fact that the theory leaves out of the picture the features of the subject and their motivation in performing a task: how much effort they put in the processing, and the how open and flexible their processing is.

The Affect Infusion model (Forgas, 2002) takes into account an individual's motivation performing a task. It integrates the notion of mood-congruence assumed non-negotiably by the spreading activation model, and the idea of heuristics-based judgments promoted by the Affect-as-Information hypothesis. Affect infusion, or the tendency to perceive information in a mood-congruent way, is a spectrum-based phenomenon, and the degree to which it engages depends on the individual's motivation, which in its turn is determined by the task at hand. The model differentiates between four types of processing strategies summarised in *Table* 1.

Table 1. Processing strategies according to the Affect Infusion model (Forgas, 2002). Degree of mood infusion is determined by the background colour: the darker the colour, the stronger the mood congruence effects.

	Closed and not constructive	Open and constructive
Effortful	Motivated processing *(engaging in a prolonged activity with a clear aim)*	Substantive processing *(engaging in a demanding task with no correct answer or single solution)*
Effortless	Direct access *(recalling particular information)*	Heuristic processing *(no particular focus on anything, limited interest, attention and motivation, low cognitive capacity)*

Mood congruence manifests itself the most during the open types of processing, whereas tasks demanding focused attention are less affected by mood fluctuations. In addition, the degree of effort put into the task positively correlates with the degree of mood congruence. Evaluative judgments during heuristic processing are congruent with mood due to the unconscious mapping of mood valence onto a stimulus, as the Affect-as-Information model predicts. If the task calls for direct attention to affective properties of the stimulus (as in evaluation), associative network mechanisms will operate, since memory nodes will get activated.

2.2.3 Mood in affective language processing

It is natural to expect that mood will modulate processing of emotional words similarly to any kind of emotional stimuli. The Affective Language Comprehension model (van Berkum, 2018) specifically targets the processing of emotional language. According to the model, when decoding an incoming message, semantic meanings are retrieved, grammatically combined and interpreted in a pragmatic context, and both the inherent properties of the message, and the context may cause affective stimulation of the recipient. As the sign is recognised and parsed, the lexical meaning is retrieved from long-term memory and mapped against the constraints of the immediate linguistic context. If the stimulus itself has inherent affective properties, it will also induce an affective response, in line with the Grounded Cognition model (Barsalou, 2008). When the stimulus is interpreted in a broader communicative context, factors like the communicative intent of the sender and their stance may alter the semantic content of the stimulus itself so it complies with the context. This may result in a word that is inherently negative to be perceived as neutral or positive if the context justifies such an interpretation.

It seems reasonable to assume that the recipient's personal emotional state may be seen as part of such pragmatic context. If moods are not necessarily consciously perceived and, unbeknownst to the recipient, modulate their processing style, the meaning of a word as it is retrieved will be affected by the mood. Corresponding conceptual representation will be both recalled and reconstructed in this process, and certain inferences of the word may or may not be triggered. The question arises about the direction in which the incoming emotional verbal information will be skewed depending on the mood, and the timing of such effects – matters that have been addressed in behavioural and electrophysiological research on mood and language.

2.2.4 Event-related potentials and the study of mood

In an experimental setting, mood is induced by the researcher in a set of mood induction procedures (MIPs), which are an established technique for ethical and valid elicitation of a certain mood in the laboratory and a prerequisite of experimental mood research. Mood induction is most commonly performed by means of exposing participants to emotional images film or music, although other methods also exist (review of MIPs in Joseph et al., 2020; Siedlecka & Denson, 2019; Westermann et al., 1996).

In addition to the emotion-modulated ERPs like the EPN and the LPC, studies of mood and language explore the marker of semantic integration, N400. It is a negative potential over centro-parietal sites with a slightly more right distribution for written language (Kutas & Federmeier, 2011, p. 2). For visually presented words, it has an onset at 200 ms post-stimulus, peaks at around 300 – 500 ms, and lasts for about 300 ms (Swaab et al., 2012, p. 398). In affective language comprehension, this corresponds to the stage when words have already been identified as emotionally salient and lexical representations are being retrieved and contextually embedded. Larger N400 amplitudes point at difficulties when processing semantic features of stimuli in context (Kutas & Federmeier, 2011). In emotional language studies, higher amplitudes have been elicited by stimuli that are emotionally incongruent with the preceding context (Schirmer & Kotz, 2003). Decontextualised emotional words have been found to elicit the lowest N400 amplitudes among the other stimuli – abstract, concrete and pseudowords – which underlines facilitated processing of emotional language (Blomberg et al., 2020).

In mood studies, higher N400 amplitudes have been elicited primarily in a positive mood (Chwilla et al., 2011; Egidi & Nusbaum, 2012; Naranowicz et al., 2022; Pratt & Kelly, 2008). Processing stage also seems to be a factor. Kiefer at al. (2007) studied mood congruence effects in a memory encoding task across the N400 and LPC windows, to find an increased left lateralised N400 during its onset, within 200 – 350 ms, where negative words caused more negativity in a positive mood. No such effect was found after 350 ms. Kissler and Bromberek-Dyzman (2021), on the contrary, only found mood congruence in the LPC window in an evaluation task.

Behavioural data does not support a full-fledged mood-congruence either. While earlier behavioural studies had found evidence for mood-congruence effects during affective word processing (review in Sereno et al., 2015, pp. 2 – 3), after addressing methodological concerns those results have not been replicated (Pratt & Kelly, 2008; Sereno et al., 2015).

2.2.5 Summary

Mood unconsciously affects the way people perceive information by way of modulating attention and motivation. A positive mood stimulates approaching behaviour, broadens attention, speeds up processing and facilitates information encoding. A negative mood promotes withdrawal and detail-oriented, analytical processing which is relatively slow. Mood can modulate processing of affective stimuli in a congruent way. Congruence effects on affective judgments are accounted for by the Affect-as-Information hypothesis (Schwarz, 2012), which operates in contexts where attention is dispersed and processing is effortless. The spreading activation model (Bower, 1981; Collins & Loftus, 1975) explains a facilitation of congruent stimuli when episodic or long-term memory is activated. Yet, mood congruence effects are not consistent and mostly occur in a good mood during later processing stages, pointing at an additional factor that might be at play during evaluative judgments in non-neutral moods. Adaptive strategies of assimilation and accommodation might be able to shed some light on mood-effected processing, as during these processes both the semantic structure of memory and the input properties are considered to be prone to change.

2.3 Research questions and hypotheses

The thesis aims at improving the understanding of the way a broader affective context alters the perception of emotional valence in written words during both automatic and reflective stages of their processing. While some research has already been conducted in this domain, the results lack consistency, which may hint at the fact that the theoretical foundation does not account for all the factors at play, and more exploration is needed. Similar studies (e.g., Kissler & Bromberek-Dyzman, 2021) explicitly state that more research is required to build conceptual credibility of the results, and the present thesis builds on this fact. In addition, experiments using mood induction procedures often only include one or two induced moods, with no control. An inclusion of a neutral, non-mood-induced condition in this study makes it possible to draw comparisons between induced and neutral affective states, using the neutral state as a baseline.

The research questions and hypotheses, as well as test implications (TIs) from hypotheses are listed below.

RQ1: Does mood modulate the processing of emotional valence of words?

H1: Processing of emotional valence in words is affected by mood.

TIs:

- Reaction times in mood-induced conditions are faster than in a neutral mood.
- Attributed valence during mood-induced conditions is significantly different from the predefined valence.
- There is a significant modulation of the EPN, N400 and LPC amplitudes in mood-induced conditions as compared to the control.

RQ2: Do mood effects on valence manifest themselves across the earlier and later stages of word processing?

H2: Mood affects valence processing both during the automatic and reflective stages of word processing.
TIs: Mood-congruent words are facilitated in the EPN (automatic), and N400 and LPC (reflective) time windows.

RQ3: Are modulations of emotional valence mood-congruent?

H3: Only a positive mood modulates valence perception in a congruent way.
TIs:

- There is a mood-congruent acceleration in RTs in a positive mood.
- Mood-congruent words elicit smaller EPN and greater LPC amplitudes in a happy mood.
- Mood-incongruent words elicit greater N400 amplitudes in a happy mood.

Facilitation is operationalised as a reduction in reaction time; as a reduced N400, since it would indicate a reduced cloze probability; a reduced EPN, since this component signals automatic attention allocation to the emotional nature of a stimulus, and the lower the amplitude, the faster and easier the disengagement from the stimulus; and finally, an increased LPC, since this would point at a successful relocation of attention to the stimulus, and higher amplitudes would stand for increased attention. Words are presented visually to make the study comparable with previous research and because of ease of stimulus control, to avoid factors like emotional prosody when words are presented in the auditory modality.

3. Method and materials

3.1 Participants

Twenty-one native English speakers between 18 and 40 years old (12 women, M = 30.2, SD = 7) were recruited via advertising on social media and university campus. All participants were right-handed, had normal or corrected-to-normal vision, and no reported mood, psychiatric or neurological disorders. Previous studies suggested a delayed valence processing in L2 (Kissler & Bromberek-Dyzman, 2021), signalling a reduced emotional sensitivity in L2, linked to a later age of acquisition and a lower frequency of use (Naranowicz et al., 2022, p. 2). For this reason, research was conducted among L1 speakers only. All participants reported English as their dominant language in daily use (the probability of choosing English as a language 87% for reading and 77% for speaking, they were exposed to English on average 77% of the time they speak a language). They had an average of 19 years of education, and 90% had a university degree. Linguistic information about the participants is summarised in *Table* 2.

Table 2. Linguistic information about participants, based on a modified version of Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007). Given are mean values and standard deviation in brackets.

Self-reported level of proficiency (on a scale from 1 to 10)		Age of acquisition (years)		Current exposure to the language across contexts (degree on a scale from 1 to 10)	
Speaking	9.5 (0.7)	Speaking	1 (1.7)	Interaction with friends	8.2 (2.6)
Reading	9.6 (0.7)	Reading	4.2 (1.3)	Interaction with family	7.3 (3.7)
Listening	9.7 (0.6)			Reading	8.2 (2.1)
				Auditory information	7.8 (2.1)

All participants were informed about the nature of the experiment in oral and written form and signed a form of consent (*Appendix 6*). The researcher ensured that each participant had a full understanding of the risks and responsibilities in relation to the mood induction procedure. Prior to the experiment, prospective participants were explicitly informed about the deeply emotional nature of the mood inducing images. The types of depicted situations were described to them in general terms to enable the volunteers to make an educated decision about participating. The vagueness necessary to avoid a bias in the results was eliminated post-experiment in a debriefing session, where the purpose of the study was explained to them in more detail. The participants maintained a full opportunity to withdraw from the experiment at any time without any repercussions or a need to state the reason for withdrawal (Mallinson, 2018).

3.2 Verbal stimuli

120 positive, negative and neutral English words (nouns, adjectives and verbs, unbalanced for part of speech, since the components in question have been shown to be insensitive to this factor: Hajcak et al., 2012, pp. 447 – 450) to serve as verbal stimuli have been selected from the Affective Norms for English Words (ANEW), a set of words previously rated for valence and arousal (Bradley & Lang, 2017). *Table* 3 gives an example of the stimuli. *Appendix 7* lists the words.

Table 3. Example stimuli.

Word	Valence	Arousal	Concreteness	Frequency	Syllables	Letters	Valence type
snuggle	7,92	4,16	3,52	3,03	2	7	positive
vacation	8,16	5,64	3,14	3,36	3	8	positive
history	5,24	3,93	2,96	3,79	3	7	neutral
whistle	5,81	4,69	4,42	4,25	2	7	neutral
corrupt	3,32	4,67	2,03	3,69	2	7	negative
poverty	1,67	4,87	2,54	4,39	3	7	negative

Units of measurement and source: Valence and Arousal on a scale from 1 (low) to 9 (high) from ANEW, Bradley & Lang (2017); Concreteness on a scale from 1 (abstract) to 5 (concrete) from Brysbaert et al. (2014); zipf frequencies from SUBTLEX_UK, van Heuven et al. (2014); Syllables in number of syllables; Letters in number of letters.

The selected words differed in valence and were balanced for arousal, concreteness, frequency, word length in syllables and letters. Mean values for verbal stimuli are presented in *Table* 4. The difference in arousal is determined by the way words are distributed within ANEW: words of neutral valence are generally lower in arousal than valenced words.

Table 4. Mean values for valence and other controlled variables for verbal stimuli.

	Positive words M (SD)	Neutral words M (SD)	Negative words M (SD)
Valence	7.3 (0.5)	5 (0.6)	2.6 (0.6)
Arousal	5 (0.5)	4.8 (0.8)	5 (0.6)
Concreteness	3.6 (1.1)	3.7 (1.1)	3.5 (1)
Word frequency (zipf)	4.1 (0.7)	4 (0.7)	3.9 (0.6)
Word length (syllables)	1.9 (0.7)	1.9 (0.7)	1.9 (0.7)
Word length (letters)	6 (1.6)	6 (1.5)	6 (1.4)

Units of measurement and source, same as above: Valence and Arousal on a scale from 1 (low) to 9 (high) from ANEW, Bradley & Lang (2017); Concreteness on a scale from 1 (abstract) to 5 (concrete) from Brysbaert et al. (2014); zipf frequencies from SUBTLEX_UK, van Heuven et al. (2014); Syllables in number of syllables; Letters in number of letters.

The 360 words were collapsed into three pseudorandomised blocks of 120 trials, each containing 40 low valence, 40 high valence and 40 neutral words, which is a recommended number of trials per condition (Luck, 2014, p. 262 – 263), with the variables of arousal, concreteness, frequency and length controlled for. Each block was further collapsed into three equal and balanced subsets.

3.3 Pictorial stimuli for mood induction

Two sets of 60 images were selected from International Affective Picture System (IAPS), a picture database developed at the University of Florida's Center for Emotion and Attention to study affective processing by the brain (Lang et al., 2008). The methodology used by the researchers to rate the images was similar to that used to affectively evaluate the words in ANEW, and the distributions of the images and words along affective dimensions are comparable. This made it possible to compile lists of verbal and pictorial stimuli with comparable ratings on the scales of valence and arousal (*Table 5*).

Table 5. Mean values for valence and arousal for pictorial stimuli.

	Positive mood M (SD)	Negative mood M (SD)
Valence	7.5 (0.4)	2.6 (0.4)
Arousal	5 (0.9)	5.4 (0.7)

The reason for choosing to induce mood via images was primarily the shared framework and methodology used by the IAPS and ANEW creators. Besides, mood induction via images, especially of faces, is among the most common and effective ways of manipulating mood in experimental research (Joseph et al., 2020; Siedlecka & Denson, 2019; Westermann et al., 1996).

3.4 Mood induction procedure

Although the IAPS has been successfully used in MIPs (Siedlecka & Denson, 2019; Westermann et al., 1996), certain aspects of its use cannot be neglected. The persistence of MIPs seems to be affected by the cognitive load during the main task. Besides, induced changes in valence are generally more stable than those in arousal. Finally, mood induced by the IAPS is relatively stable for two minutes post-induction, diminishing quickly after that, to return to the baseline within approximately eight minutes, depending on the emotion (Kuijsters et al., 2016). For these reasons, the 60 images in each condition formed blocks of 20. The images were projected, one at a time, in random order, for 5 s, with a total presentation time of 100 s per block.

Explicitly given instructions to feel the emotion being induced by the stimuli has only been shown to increase the effectiveness of MIPs for films (Joseph et al., 2020). Besides, it is unclear whether the effect of such instructions is actual mood induction by the stimulus or an artificial cognitive inflation. For these reasons, the participants were only asked to focus on the images while passively viewing those.

Manipulation check was performed immediately after MIP via Self-Assessment Manikins (SAM) (Bradley & Lang, 1994) (*Figure 1*). A pen-and-paper version of SAM was used, preceded by the instruction: “Please mark exactly how you feel”. Without its reliance on language, SAM prevents priming or early exposure to words the participants may encounter further in the experiment. Besides, being quick and low on cognitive effort, it is less likely to impede the persistence of an induced mood.

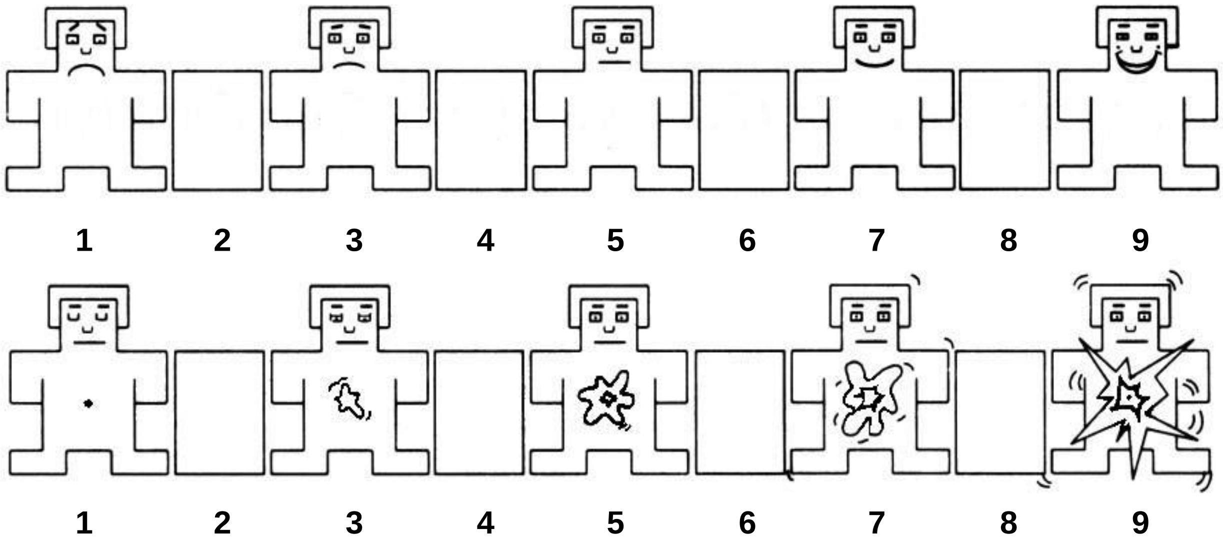


Figure 1. Self-Assessment Manikins (Bradley & Lang, 1994).

3.5 Mood reset post-experiment

Despite the fact that negative emotions elicit a stronger response in mood induction than positive ones (negativity bias explained by the automatic vigilance hypothesis, Pratto & John, 1991), the effect of negative emotions is more short-lived. This is explained by the positivity offset: healthy individuals tend to experience positive emotions overall (Joseph et al., 2020). Even so, to facilitate emotional recovery and bring the effect of a negative mood induction to an absolute minimum, each experiment was concluded by a final slideshow of positive images. Although research on such resetting procedures is limited, the data available show that it may not only lead to the participants’ mood returning to the baseline, but getting better than prior to the experiment (ibid).

3.6 Procedure

The experiment was conducted in the EEG room of the Humanities Lab at Lund University. Upon arrival at the laboratory, the participants were familiarised with the setting and introduced to the EEG equipment. The purpose of the study was outlined in general terms as a study of emotional language processing. While the electrodes were being attached, the participant filled in a personal information and selected medical history form (*Appendix 1*); a modified version of the Edinburgh Handedness Test (Oldfield, 1971, *Appendix 2*); a modified version of Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007, *Appendix 3*); Depression Anxiety Stress Scales (DASS-21), a standardised psychometric test for common mood disorders designed to self-assess one's level of depression (Lovibond & Lovibond, 1995, *Appendix 4*); Positive and Negative Affect Schedule (PANAS), a brief questionnaire to measure their prevailing mood over two weeks prior to the experiment along the dimensions of valence and arousal (Watson et al., 1988, *Appendix 5*); and finally Self-Assessment Manikin (SAM) to measure their current mood on the bipolar scales of the same dimensions of valence and arousal (Bradley & Lang, 1994, *Figure 1*). After the electrode placement, the participant were given an overview of the experiment stages and given instructions. The experiment had a within-subject design, hence each participant was engaged in three measurement sessions. The measures from the questionnaires, collected before the experiment, were analysed before the analysis of the behavioural and ERP data ensure that the group was homogenous (summary in *Table 6*).

Table 6. Participant characteristics, mean values, with standard deviations in brackets.

Handedness	89.2 (20.2)
Depression	6.6 (4.2)
Anxiety	5.4 (5.1)
Stress	13.6 (7.8)
Positive affect	32.2 (7.5)
Negative affect	18.4 (5.4)

Units of measurement and source: Handedness from -100 (strong left-handedness) to 100 (strong right-handedness) (adapted from Oldfield, 1971). Depression, Anxiety and Stress from DASS-21 (Lovibond & Lovibond, 1995), the scores fall in the category of normal to mild for Depression, normal to moderate for Anxiety, and normal to moderate for Stress. Positive and Negative affect based on PANAS (Watson et al., 1988).

The experiment was conducted on a stationary Windows computer, the stimuli were designed and projected using PsychoPy. The participant was seated in a chair in front of the screen. In a semantic decision type task (evaluative decision), they were instructed to evaluate the word on a 5-point Likert scale, from least to most pleasant. They responded by pressing keys on the keyboard with their right hand. The words were presented one at a time in lowercase letters against a grey background. Ten trials with words not used further in the experiment were held for training purposes.

The choice of task is motivated by the necessity to draw attentional resources to emotional valence of the stimuli, since the LPC and possibly the EPN are sensitive to how focused a participant is during performance. According to the Affect Infusion model (Forgas, 2002), the task is moderately effortful and has a clear aim, meaning that some level of mood congruence is expected, and that it should be accounted for by spreading activation.

The baseline condition came first, followed by two mood induced conditions, with positive mood induction coming second for half of the participants. MIP was carried out in three stages; each time the image presentation (n=20) was followed by a manipulation check performed via SAM, and then by a verbal stimuli subset (n=40). All the participants were exposed to both mood inductions. The positive and negative mood induction was counter-balanced between participants. Trial blocks and trials were presented in random order within each mood condition with self-paced pauses in between.

The stimulus duration of 800 ms was followed by a question mark displayed for 1000 ms. To avoid muscle artefacts in the epoch window, the participants were instructed to only evaluate the word when they saw the question mark on the screen. This was followed by an inter-trial interval (ITI) of 500 ms, during which a blank screen was displayed for 500 ms. This was followed by a fixation cross signalling the beginning of the next trial. The inter-stimulus interval (ISI) equalled 2 s allowing the possible tail of the LPC to subside. *Figure 2* summarises the design of a single trial.

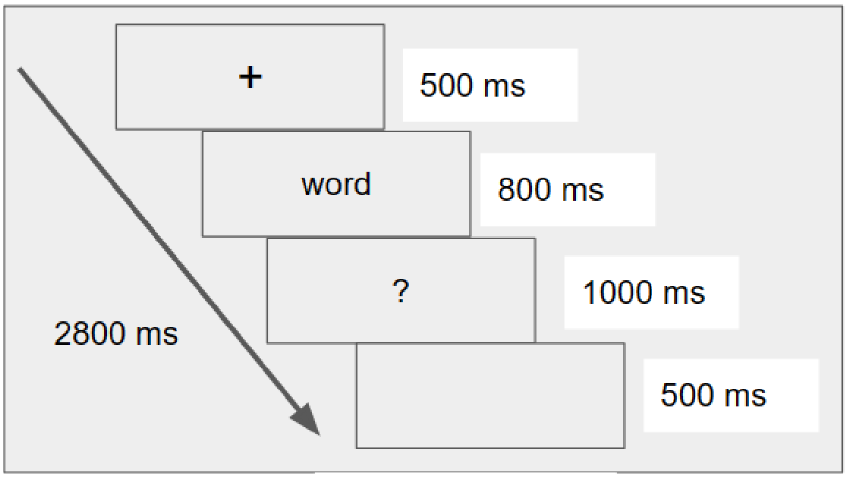


Figure 2. A single trial of a measurement session

3.7 EEG recording and data pre-processing

EEG signals were recorded from 62 scalp electrodes using *Easycap* and a *Synamps 2* amplifier. The electrodes were placed following the extended International 10/20 System (*Figure 3*), with the ground at AFz. Two electrodes were placed at the canthi of the eyes to monitor horizontal eye movements (HEO) and two above and below the left eye to monitor vertical movements (VEO). Two electrodes were placed on the mastoids. EEG was sampled at 1 000 Hz/channel using *Curry 7* by *Neuroscan*, and referenced to the Cz electrode online. Impedances were kept below 5 kΩ for scalp electrodes, below 2 kΩ for the mastoids, and below 10Ω for the eye electrodes. ERPs were time-locked to the onset of each word.

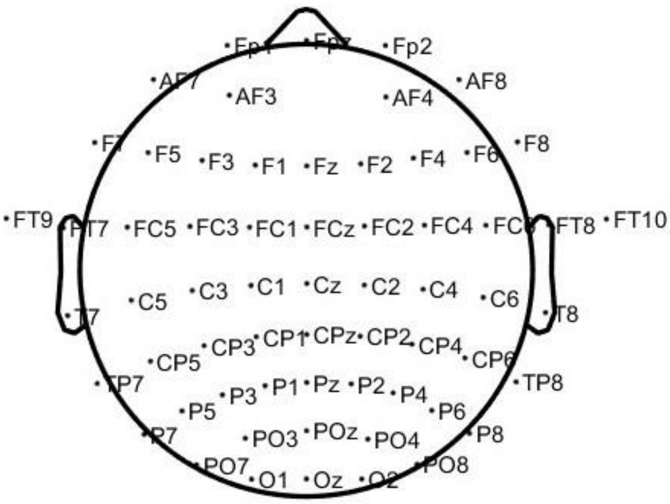


Figure 3. Locations of the scalp electrodes

EEGLab (version 2022.1) (Delorme & Makeig, 2004) was used to analyse the data offline. During pre-processing, a bandpass filter was applied with a high-pass cut-off point at 0.05 Hz and a low-pass cut-off point at 30 Hz to remove high frequency noise. The scalp EEG channels were re-referenced to the average. Average reference was chosen based on the components to analyse (Luck, 2014, p. 156 – 162). The EPN is prominent near mastoid electrodes, and can get subtracted if averaged mastoid reference is selected; the LPC, on the contrary, is more prominent when mastoid reference is used, especially in the later window (Hajcak et al., 2012, p. 454). That being said, previous studies of emotion and mood most often apply average reference (e.g., Kiefer et al., 2007; Kissler & Bromberek-Dyzman, 2021; Ogawa & Nittono, 2019). Ocular artefacts were identified and removed using the Independent Component Analysis (ICA) through the function *runica* in EEGLab. Continuous data were segmented into epochs from a 200 ms baseline before stimulus onset to 800 ms post-stimulus; baseline correction was performed. Epochs exceeding ±100 μV were removed. For two participants, 11 and 14% of epochs were rejected, and no more than 2% of the trials were rejected for the other participants. Overall, the number of rejected epochs across participants did not exceed 2%, with a total of 140 epochs rejected across a total of 7 560 trials.

ERPs were averaged across conditions and participants and analysed in three time windows for the three components of interest: EPN (200 – 350 ms), N400 (300 – 500 ms) and LPC (500 – 700 ms). The time windows correspond to the previous studies (e.g., Abbassi et al., 2011; Chwilla et al., 2011; Herbert et al., 2008; Imbir et al., 2015; Kiefer et al., 2007; Kissler & Bromberek-Dyzman, 2021; Ogawa & Nittono, 2019; Wu et al., 2021; Zhang et al., 2017). The EPN was analysed across two symmetrical parieto-occipital regions of interest (ROIs): left (P7, P5, PO7, O1) and right (P8, P6, PO8, O2) (Hajcak et al., 2012, p. 447). For N400, a central ROI included electrodes FCz, Cz, CPz, C1/2, CP1/2, C3/4 (Kutas & Federmeier, 2011). The LPC was analysed across three parietal ROI: midline (CPz, Pz, POz), left (CP3, P1, PO3) and right (CP4, P2, PO4) (Hajcak et al., 2012, p. 449). ROIs across the selected components are shown in *Figure* 4.

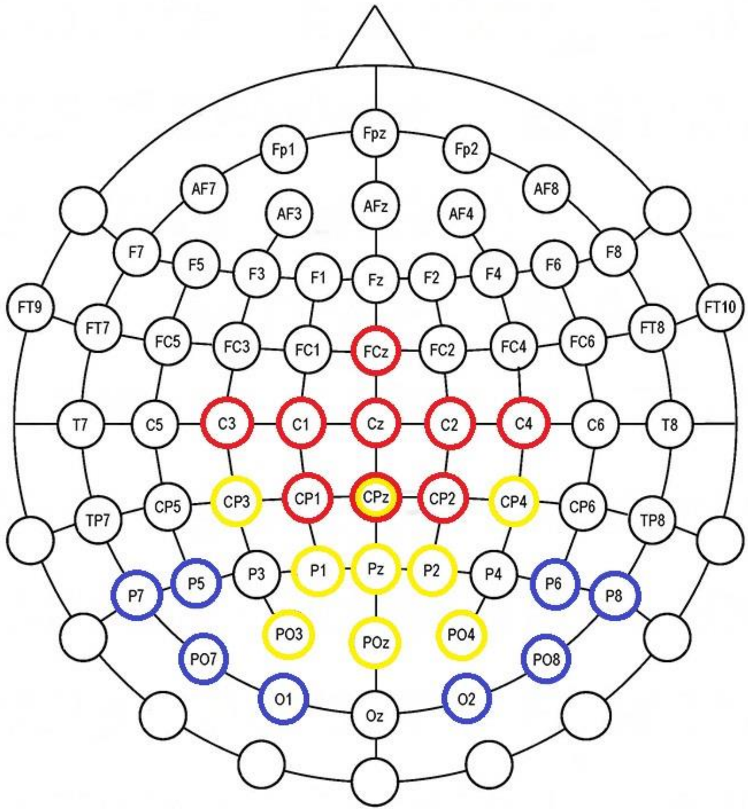


Figure 4. Electrode sites across ROIs: EPN (blue), N400 (red), LPC (yellow).

3.8 Statistical analysis

Statistical analysis was conducted in R (version 4.2.3) via RStudio (version 2023.03.0) (R Studio Team, 2022). Analysis of variance was conducted using the *afex* package (version 1.2-1) (Singmann et al., 2023). Post-hoc analyses were performed via the *emmeans* package (version 1.8.5) (Lenth, 2023).

To evaluate the effectiveness of mood induction, a manipulation check was conducted based on self-reported ratings of arousal and valence. To calculate whether the difference between the baseline and mood induced conditions was significant, paired sample t-tests were performed. In a paired-sample t-test, measurements of each subject or item are taken twice. The tests require that the samples be dependent and the variables quantitative (Loftus, 2021, p. 179 – 180). Both these criteria were met. The test was conducted to learn whether the independent variable (picture valence) affects the dependent variable (induced mood via self-reported rating of valence and arousal). Because of the small sample size (n<50), a univariate

Shapiro-Wilk test for normality was performed on the difference scores (between baseline and positive induction, and between baseline and negative induction). This test rejects the hypothesis of normality when the p-value is less than or equal to 0.05, meaning that if a Shapiro-Wilk test delivers a $p>0.05$, the data follows a normal distribution (Gries, 2013, p. 329). If the distribution is normal, a paired sample t-test can be run on the dataset.

For the analysis of both behavioural and ERP data, a repeated-measures analysis of variance (RM ANOVA) was conducted with the factors of Mood (Positive, Negative, Baseline) and Valence (High, Low, Neutral) for behavioural data and N400. For the EPN and LPC, the factor of Laterality (Left, Right) was added to assess expected asymmetries across the hemispheres. RM ANOVAs are used for within-subject designs, where measurements of the same outcome variable are taken from the same participants more than once, in multiple conditions. Two- and three-way RM ANOVAs evaluate the effect of, respectively, two or three factors on a continuous outcome variable, such as the ERP amplitude change in μV.

Before performing RM ANOVAs, the datasets were examined for outliers, and extreme outliers were removed. Since the distribution within each variable for conducting ANOVAs is to be normal, Shapiro-Wilk tests for normality were performed. The assumption of sphericity was checked by Mauchly tests, and a Greenhouse-Geisser correction was applied to factors violating the sphericity assumption. Alpha was predefined at 0.05, with 95% confidence levels.

If the ANOVAs revealed a main effect of a factor, that is, if an independent variable significantly influenced the outcome variable, with the effect of the other factors collapsed, a follow-up one-way ANOVA was carried out to explore the effect of that factor across the levels of the other independent variables. The percent of variance that is explained by the predictor with the other variables controlled for is listed as the partial Eta-squared (η_p^2), which stands for the percent of partial variance. For significant interactions, which point at the fact that the value of one factor influences the value of another, post-hoc paired sample t-tests were conducted to determine which levels were significantly affected. The pairwise comparisons were Holm-corrected.

4. Results

The chapter gives a detailed account of the results of the experiment. The success of the mood induction procedure is determined in the opening section, followed by behavioural results. Reaction times (RTs) to words of different valence across three mood conditions are compared, and attributions of valence labels is analysed. Finally, ERP results are given for the EPN, N400 and the LPC.

4.1. Mood induction

The participants rated their mood on valence and arousal scales at the beginning of the experiment. That served as the baseline, or control, mood rating. Mood was induced three times in the happy and sad condition; arousal and valence ratings were also collected after every word evaluation task, three times during either mood. To ensure that the manipulation was successful, paired sample t-tests were conducted separately for arousal and valence between the control mood and each of the mood inductions. *Table 7* lists the p-values across conditions, together with the mean across participants after each induction.

Table 7. Mean values and p-values of self-reported valence and arousal ratings across conditions.

	Control mood	Positive mood			Negative mood			Mood reset
		Induction 1	Induction 2	Induction 3	Induction 1	Induction 2	Induction 3	
Valence:								
Mean	6.5	7.2	7.1	7	4.2	4.3	4.2	6.7
p-value		0.004	0.02	0.03	<0.001	<0.001	<0.001	0.5
Arousal:								
Mean	3.4	3.7	3.6	3.4	3.9	4.1	4.2	3.5
p-value		0.3	0.5	0.9	0.2	0.05	0.03	0.8

Valence and Arousal ratings on a scale from 1 to 9.

Averaged arousal and valence scores were also contrasted with the baseline and showed that the mood induction procedure was successful for both positive and negative moods. The latter was more consistently induced ($t(20) = 7.3$, $p < 0.001$). In the positive mood, participants also rated their mood as more positive than in the control condition ($t(20) = 2.3$, $p = 0.008$). Valence showed more response to the manipulation than arousal (*Figure* 5). This was expected, as the mood-inducing images were selected with a difference in valence in mind, and arousal ratings were controlled for. The results of the mood induction are comparable to those in previous similar studies (e.g., Egidi & Nusbaum, 2012; Kissler & Bromberek, 2021).

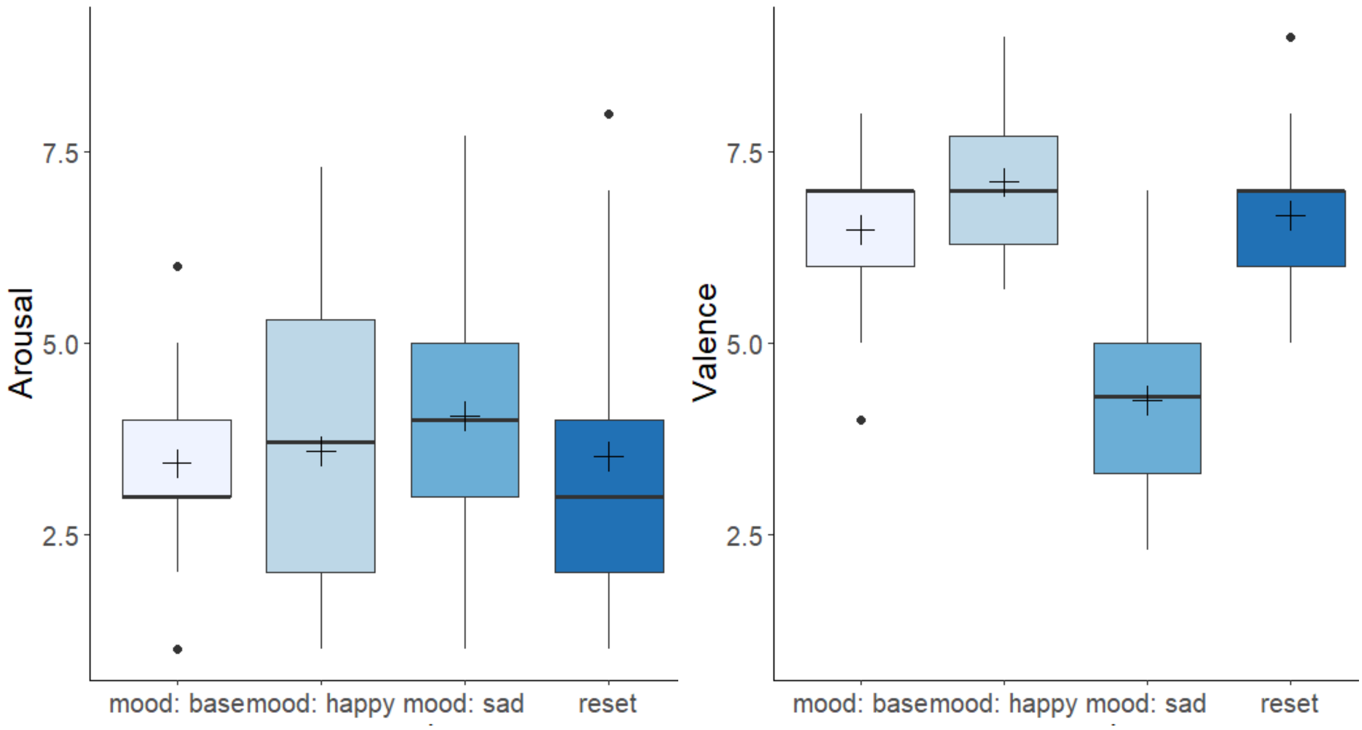


Figure 5. Valence (left) and arousal (right) scores across moods. Valence and arousal on a scale from 1 to 9. Mean scores (the average) are indicated by the cross. The thick black line represents the median – the middle value in the dataset separating the higher end of the population sample from the lower one.

4.2 Behavioural results

During behavioural data analysis, reaction times to the words were calculated, and the participants' valence judgments were examined.

4.2.1 Reaction time

The stimulus was displayed for 800 ms, and the response could only be registered after that. Therefore, due to the design of the task, all responses took at least 800 ms. Responses longer than 2300 ms post stimulus onset were excluded from the analysis. This eliminated 23% of trials. After that, mean values were calculated for each participant in each of the three moods, and the responses below and above two standard deviations of the participant's mean were rejected – these made up another 4.1% of the data. A total of 5553 trials, an average of 264 trials per participant, and 617 per condition, were available for the analysis of reaction time.

Overall, emotional words were evaluated faster than neutral ones: mean reaction time equalled 1558 ms for positive, 1551 ms for negative, and 1611 ms for neutral words. Evaluations were performed the fastest in a sad mood (M = 1545 ms), followed by a happy mood (M = 1561 ms) and the slowest response in control (M = 1615 ms). Detailed RTs across individual conditions are listed in *Table* 8.

Table 8. RT across conditions: mean values (ms), with standard deviation in brackets.

	High valence	Low valence	Neutral valence
Control mood	1589 (361)	1607 (359)	1648 (340)
Positive mood	1549 (361)	1531 (362)	1604 (371)
Negative mood	1537 (370)	1514 (356)	1538 (373)

A two-way RM ANOVA was conducted with the factors of Mood (Control, Happy, Sad) and Valence (High, Low, Neutral) to determine whether the difference in reaction times was significant and whether it points at the role of mood in processing emotional words. A main effect of valence was found [$F(2, 35) = 9.1$, $p = 0.001$, $\eta_p^2 = 0.31$], with a significant difference between RT for valenced vs neutral words (acceleration for valenced, $p = 0.008$), and none between positive and negative words ($p = 0.55$). No main effect of mood was found ($p = 0.1$).

To explore the contrasts at the individual levels of the factor of Mood, one-way ANOVAs were conducted. They revealed a valence effect in a happy [$F(2, 38) = 10.3$, $p < 0.001$, $\eta_p^2 = 0.34$] and sad [$F(2, 31) = 6$, $p = 0.013$, $\eta_p^2 = 0.23$], but not in control ($p = 0.8$) moods. Holm-corrected paired t-tests were conducted to determine significant contrasts across conditions. In a happy mood, both positive $t(20) = 3.5$, $p = 0.004$) and negative words ($t(20) = 3.9$, $p = 0.003$) delivered faster reaction times than neutral ones. This was also true in a sad mood (positive words: $t(20) = 2.4$, $p = 0.049$; negative words: $t(20) = 2.8$, $p = 0.036$). The contrasts between high and low valence words were never significant ($p > 0.1$). Distribution of reaction time across conditions is shown in *Figure* 6.

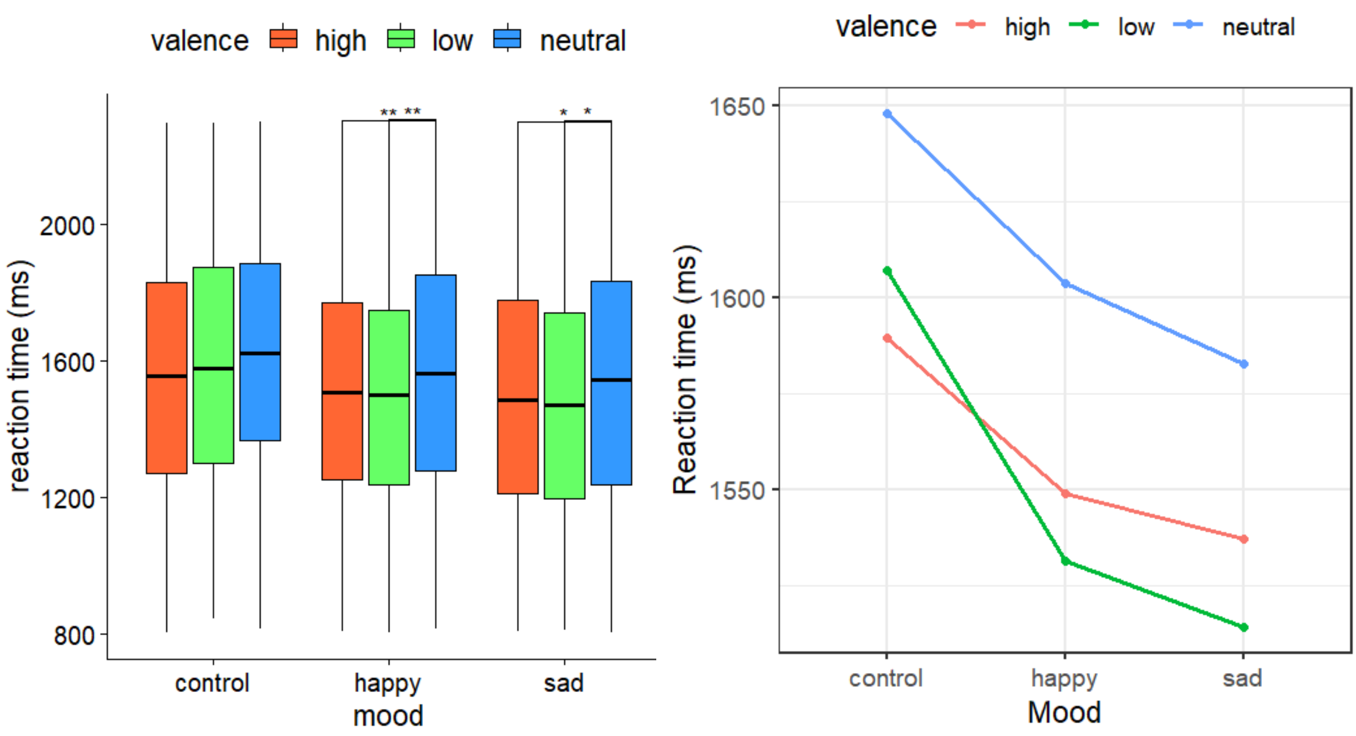


Figure 6. Distribution of RT by mood and valence. The box plot (left) shows the distribution of RTs across moods: control (right), happy (centre) and sad (left). The interaction plot (right) shows mean values to positive (red), negative (green) and neutral (blue) words in control, happy and sad moods. RTs in ms are plotted vertically.

4.2.3 Word evaluations

The participants' judgments of word valence were examined for effects of mood. A two-way RM ANOVA with the factors of Predefined Valence (High, Low, Neutral) and Mood

(Happy, Sad, Control) revealed a main effect of mood [$F(2, 28) = 6.5$, $p = 0.010$, $\eta_p^2 = 0.24$]. Subsequent one-way ANOVAs conducted to determine which levels of Predefined Valence were affected by mood showed an effect for neutral [$F(2, 35) = 10.7$, $p < 0.001$, $\eta_p^2 = 0.35$] and high valence words [$F(2, 32) = 5$, $p = 0.018$, $\eta_p^2 = 0.2$].

Paired Holm-corrected t-tests showed that all contrasts were significant in the evaluation of neutral words. Those received considerably lower ratings in a sad condition in comparison with a happy mood ($t(20) = 2.1$, $p = 0.049$) and control ($t(20) = 4.1$, $p = 0.002$), and lower in the control than happy mood ($t(20) = 2.7$, $p = 0.027$). The contrast between positive word evaluations was non-significant between a sad mood and control, with lower scores in the sad condition ($t(20) = 2.6$, $p = 0.051$). Low valence words were rated consistently across moods ($p = 0.99$) (*Figure* 7).

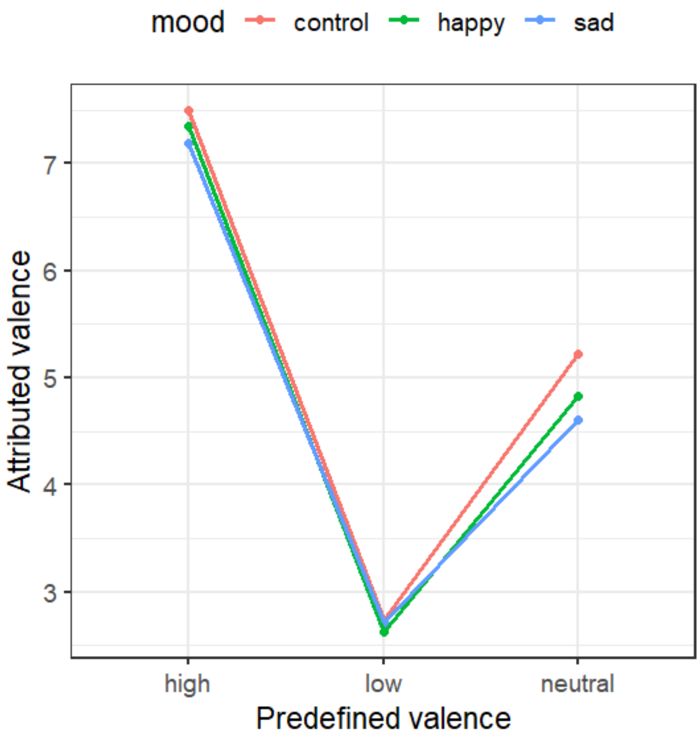


Figure 7. Ratings of high (left), low (middle) and neutral (right) valence words in control (red), happy (green) and sad (blue) mood.

Evaluations of all word categories were the highest in the control mood, exceeding the predefined levels of valence. Ratings in a happy mood were closest to the original valence scores. A sad mood affected word evaluations the most. *Table* 9 lists mean evaluation scores across conditions, and an average pre-defined rating of the stimuli.

Table 9. Word evaluations across conditions: mean value and standard deviation in brackets. Predefined valence scores were identical for all moods.

	High valence	Low valence	Neutral valence
Control mood	7.5 (1.6)	2.7 (1.8)	5.2 (2.2)
Happy mood	7.4 (1.5)	2.6 (1.6)	4.8 (2.1)
Sad mood	7.2 (1.5)	2.7 (1.4)	4.6 (2.1)
Predefined score	*7.3 (0.5)*	*2.6 (0.6)*	*5 (0.6)*

4.2.4 Correlation analysis

To test for a presence of a correlation between RT, word evaluations and self-reported mood, a correlation analysis was conducted. Mean values of the variables were compared to find whether a correlation exists, and to determine its direction and strength. Since only RT followed a normal distribution, a non-parametric Spearman test was selected. Unlike Pearson's test, which assumes a linear correlation, Spearman test is rank-based and fits for datasets with less continuity, like data acquired via Likert scale judgments (Johnson, 2013, pp. 305 – 306).

A moderate positive correlation was found between reported mood ratings and word evaluations: $r(59) = 0.36$, $p = 0.004$. A higher self-reported valence score correlated with a higher valence attributed to a word. There was also a low negative correlation between reaction times and word evaluations: $r(59) = 0.26$, $p = 0.043$, meaning that participants' response was somewhat faster the higher the valence they attributed to a word (*Figure* 8).

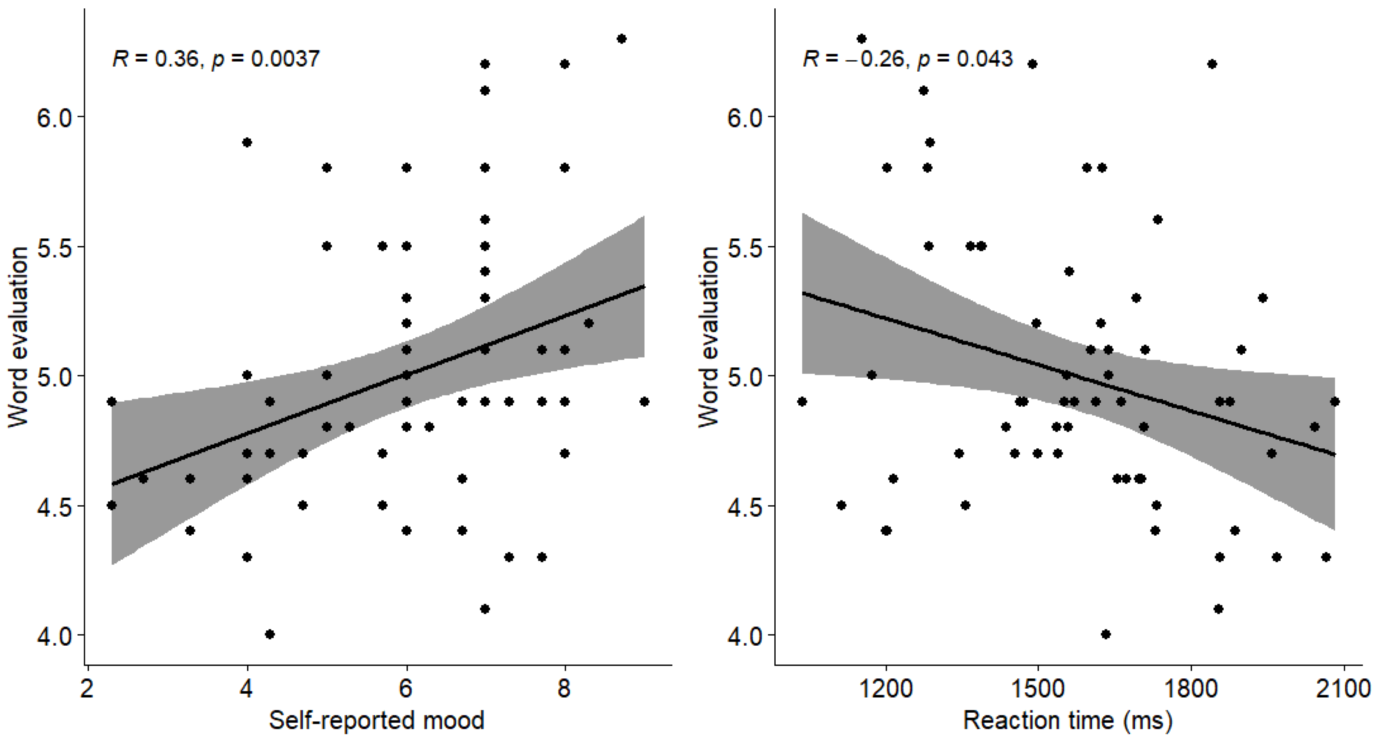


Figure 8. Correlation analysis between word evaluations and reported mood (left) and word evaluations and RT (right). The points represent averages per participant.

4.3. ERP data

4.3.1 EPN

A three-way RM ANOVA was performed in the EPN time window (200 – 350 ms) to evaluate the effect of mood and valence on the EPN amplitudes over the two hemispheres. The assumption of normality was tested in a Shapiro-Wilk test and was met ($p > 0.1$). The assumption of the homogeneity of variances was also met ($p > 0.6$ in Bartlett tests). *Figure 9* illustrates the distribution across conditions.

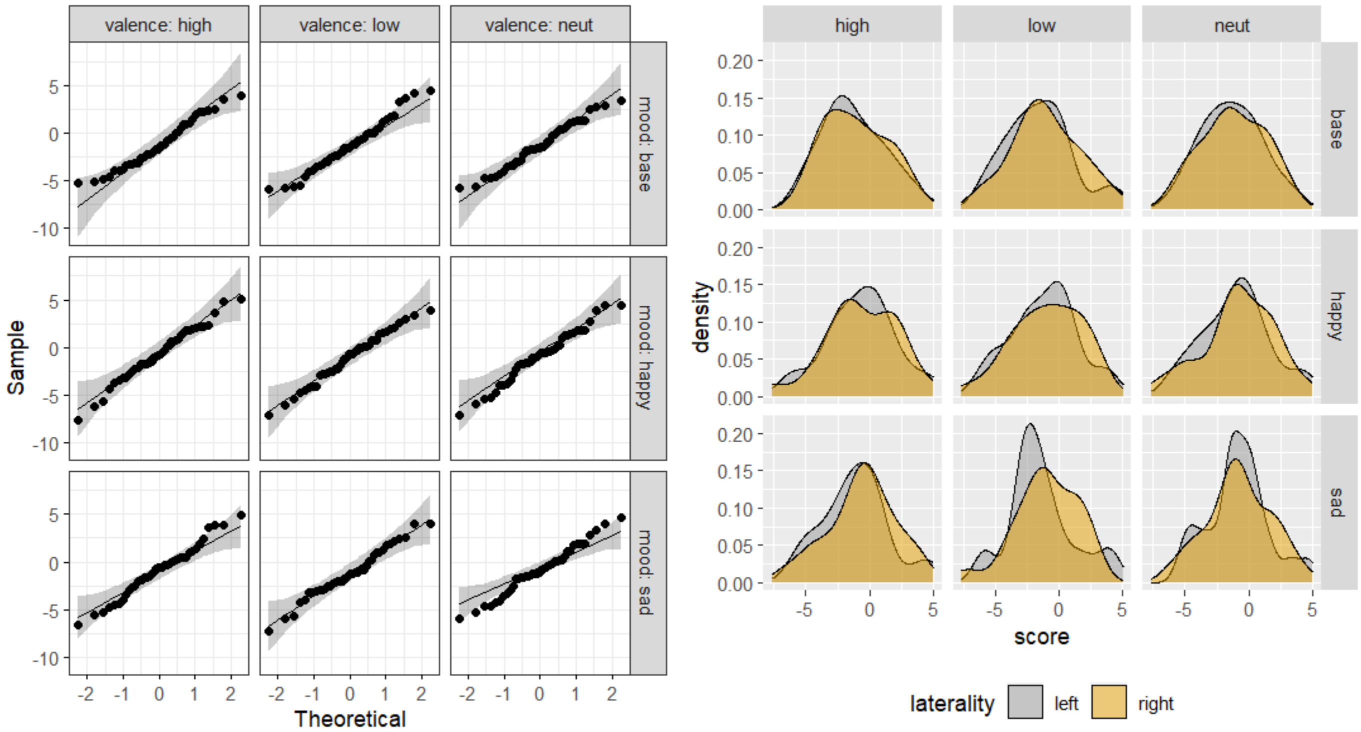


Figure 9. Quantile-quantile (q-q) plot (left) and density plot (right) of the distribution of averaged EPN amplitudes per participant and across trials.

A main effect of valence was found [$F(2, 39) = 5.32$, $p = 0.009$, $\eta_p^2 = 0.21$], whereby negative words (*M = -1.2 µV, CI (-2.3; -0.1)*) elicited a greater negativity than positive words (*M = -0.9 µV, CI (-2; 0.2), p = 0.015, t(20) = 3.1*). The difference between negative and neutral words (*M = -1 µV, CI (-2.1; 0.1)*) was not significant ($t(20) = 2.4$, $p = 0.057$).

No main effect of mood was found [$F(2, 35) = 2.9$, $p = 0.073$, $\eta_p^2 = 0.13$] and no contrasts were significant (ps > 0.1). One-way ANOVAs performed separately for each mood revealed a valence effect in the positive mood [$F(2, 40) = 4.33$, $p = 0.020$, $\eta_p^2 = 0.18$], where negative words generated a greater negativity (*M = -1.1 μV, CI (-2.2; 0.1*) than positive ones (*M = -0.65 μV, CI (-1.9; 0.5), t(20) = 2.9, p = 0.027*). *Figures 10* and *11* show a reduction in negativity in the EPN window for happy and control, and sad and control moods, respectively.

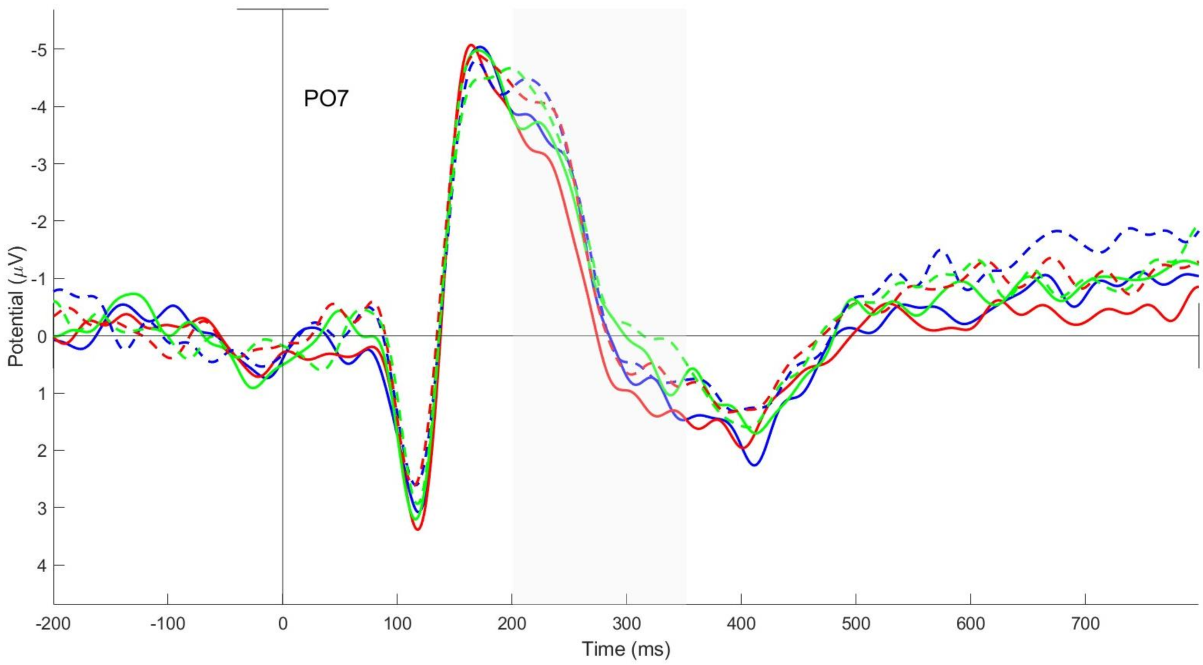


Figure 10. Averaged ERPs in a happy (solid lines) and control (dashed lines) moods, the EPN window (200 – 350 ms) in grey, red for positive, green for negative, blue for neutral words.

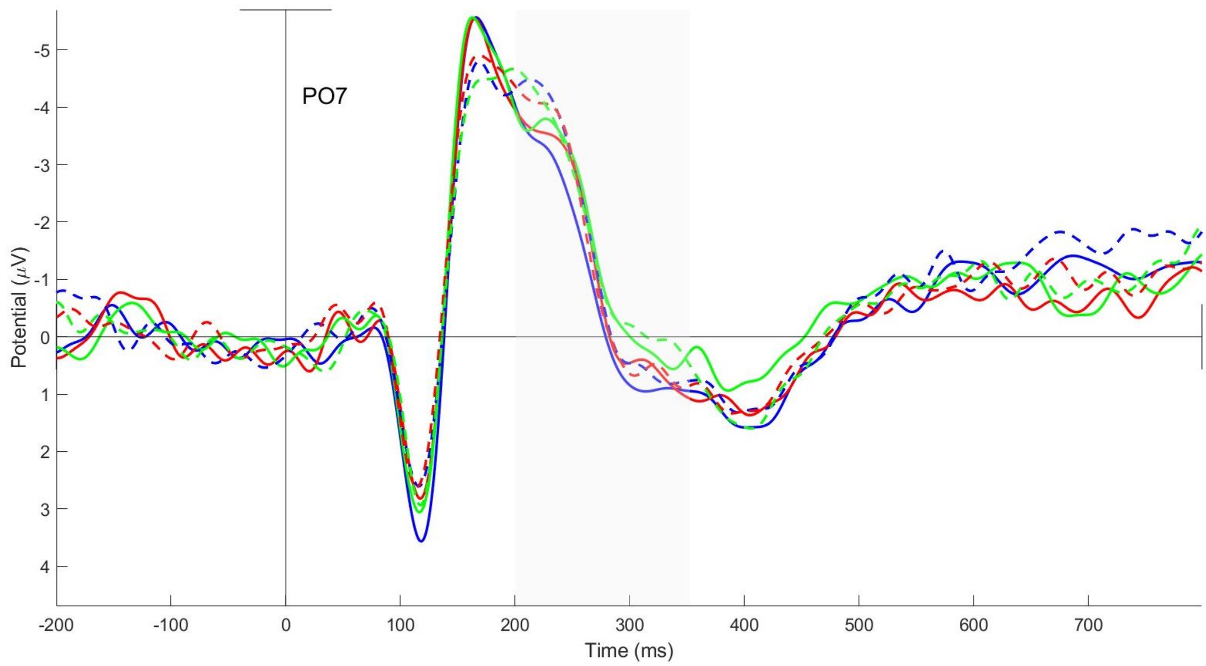


Figure 11. Averaged ERPs in a sad (solid lines) and control (dashed lines) moods, the EPN window (200 – 350 ms) in grey, red for positive, green for negative, blue for neutral words.

Analysis of the left ROI revealed an effect of valence [F(2, 40) = 7.1, p = 0.002, $\eta_p^2 = 0.26$], whereby negative words (*M = -1.4 μV, CI (-2.6; -0.2*) elicited more negativity than positive words (*M = -1 μV, CI (-2.2; 0.1)*, *t(20) = 3.5, p = 0.007*) and neutral words (*M = -1.1 μV, CI (-2.2; 0)*, *t(20) = 3.1*, *p = 0.012*). Topography for positive, negative and neutral words is seen in *Figure* 11.

Over the left ROI, an effect of mood was also found [F(2, 39) = 4.3, p = 0.021, $\eta_p^2 = 0.18$]. Amplitudes were higher in the control mood as compared to mood-induced conditions, and the difference between control *(M = -1 μV, CI (-2.2; 0.3))* and happy (*M = -1.4 μV, CI (-2.5; -0.3))* moods was significant (t(20) = 2.9, p = 0.027). No effect of valence or mood was found over the right ROI (p > 0.15). *Figure 12* shows ERP distribution over the left (P7, P5, PO7, O1) and right (P8, P6, PO8, O2) electrodes in a happy (top), sad (middle) and control (bottom) moods. Positive words are plotted in red, negative in green and neutral in blue. Smooth ERP slopes over the right hemisphere show a reduced effect.

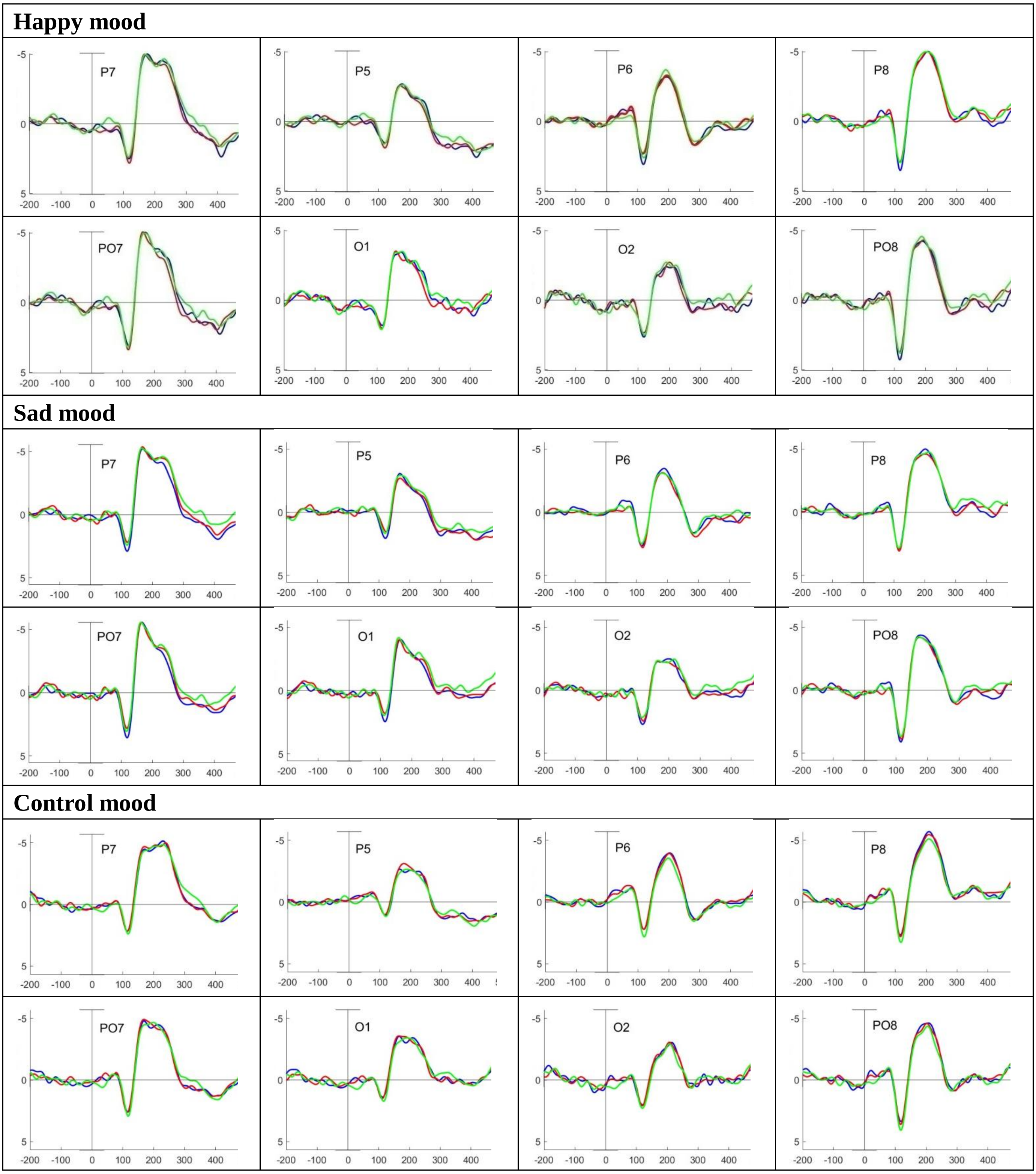


Figure 12. EPN amplitudes over left and right hemisphere electrode sites.

The analysis did not find an interaction between mood and valence on the global level, across both ROIs (p > 0.35). Over the left hemisphere, in a happy mood, negative words (*M = -1.2 µV, CI (-2.4; 0)*) elicited more negativity than positive ones (*M = -0.7 µV, CI (-1.9; 0.6), t(20) = 3.3, p = 0.011*)). This pattern was changed in a sad mood, where the amplitudes of negative words (*M = -1.2 µV, CI (-2.2; -0.1*)) were significantly higher than those of neutral words (*M = -0.8 µV, CI (-1.9; 0.3)*, t(20) = 2.7, p = 0.040)), which indicates that mood affected the amplitudes of positive words.

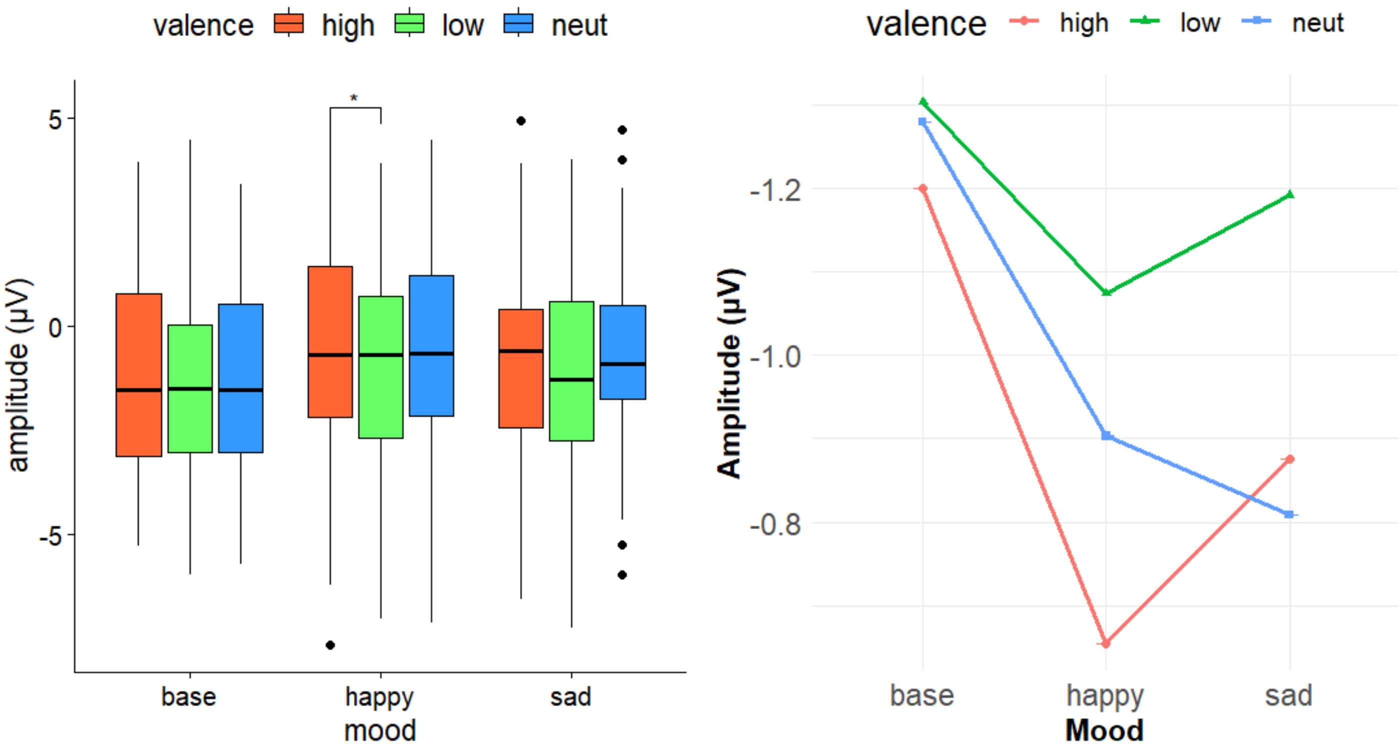


Figure 13. Distribution of the EPN data, averaged across all electrode sites in the two ROIs. The box plot (left) shows the distribution of EPN amplitudes across moods: control (right), happy (centre) and sad (left). The interaction plot (right) shows mean values to positive (red), negative (green) and neutral (blue) words in control, happy and sad mood.

To sum up, the effects found were mostly left-lateralised, and the ERPs were greater for negative words. Negative words produced greater EPNs than positive ones across the scalp, and greater than positive and neutral over the left hemisphere. Negative words also elicited a greater EPN than positive ones in a happy mood, especially in the left hemisphere. Significant contrasts are shown in *Figure 13.*

4.3.2 N400

The overall distribution of N400 amplitudes in the time window between 300 and 500 ms (dependent variable) across moods and in each mood separately failed to meet the assumption of normality ($p \leq 0.001$ in Shapiro-Wilk tests).

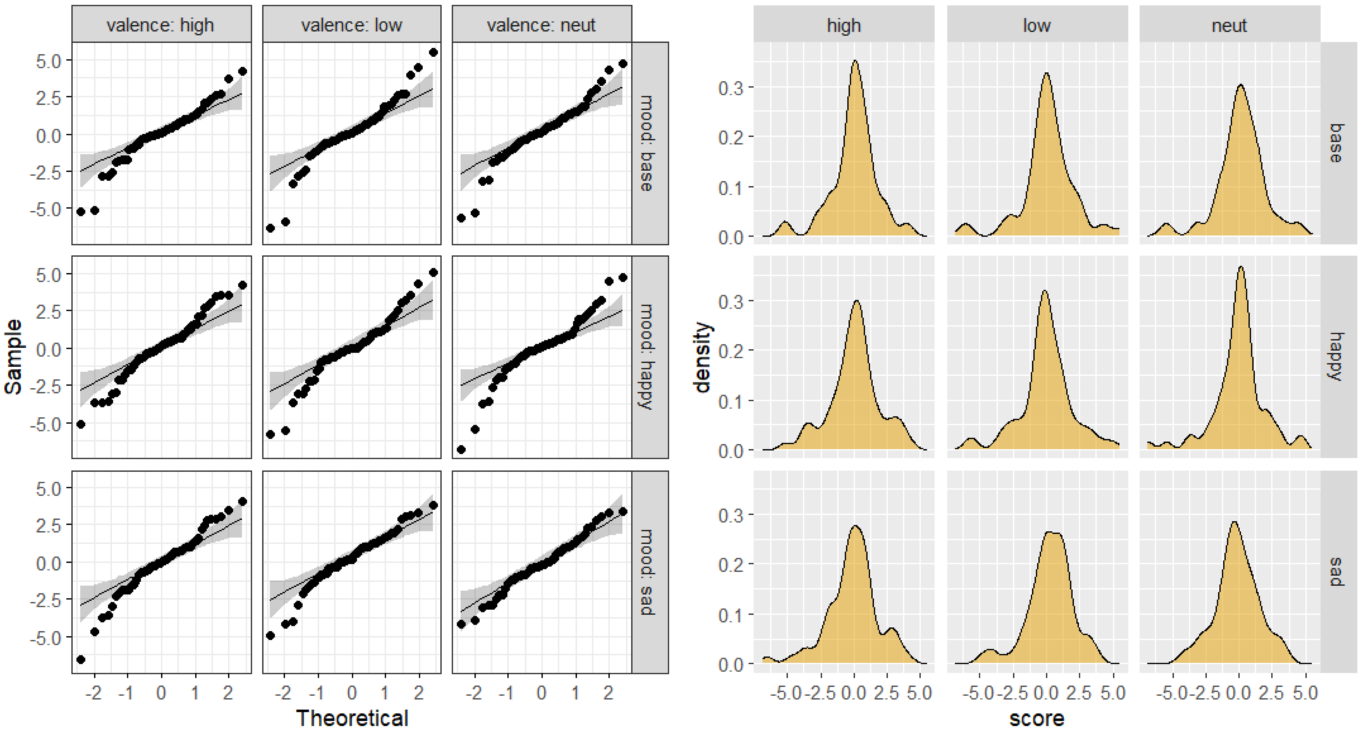


Figure 14. Quantile-quantile plot (left) and density plot (right) of the distribution of averaged N400 amplitudes across conditions.

With the assumption of normality violated, ANOVAs could not be performed. Failure to meet the assumption may be indicative of the fact that variability was too large, and might be linked to the small sample size (n=21), the small effect size, and a difference in latency in the N400 onset and peak across the sample population. To avoid Type II error, paired-sample t-tests were performed. The difference between factor levels was calculated and the difference scores were tested for normality. The distribution was normal ($p > 0.1$ in a Shapiro-Wilk test). An effect of valence was detected in a sad mood, where negative words produced significantly less negativity than positive ($t(20) = 2.1$, $p = 0.051$) and neutral words ($t(20) = 2.7$, $p = 0.015$) (*Figures 15, 16*).

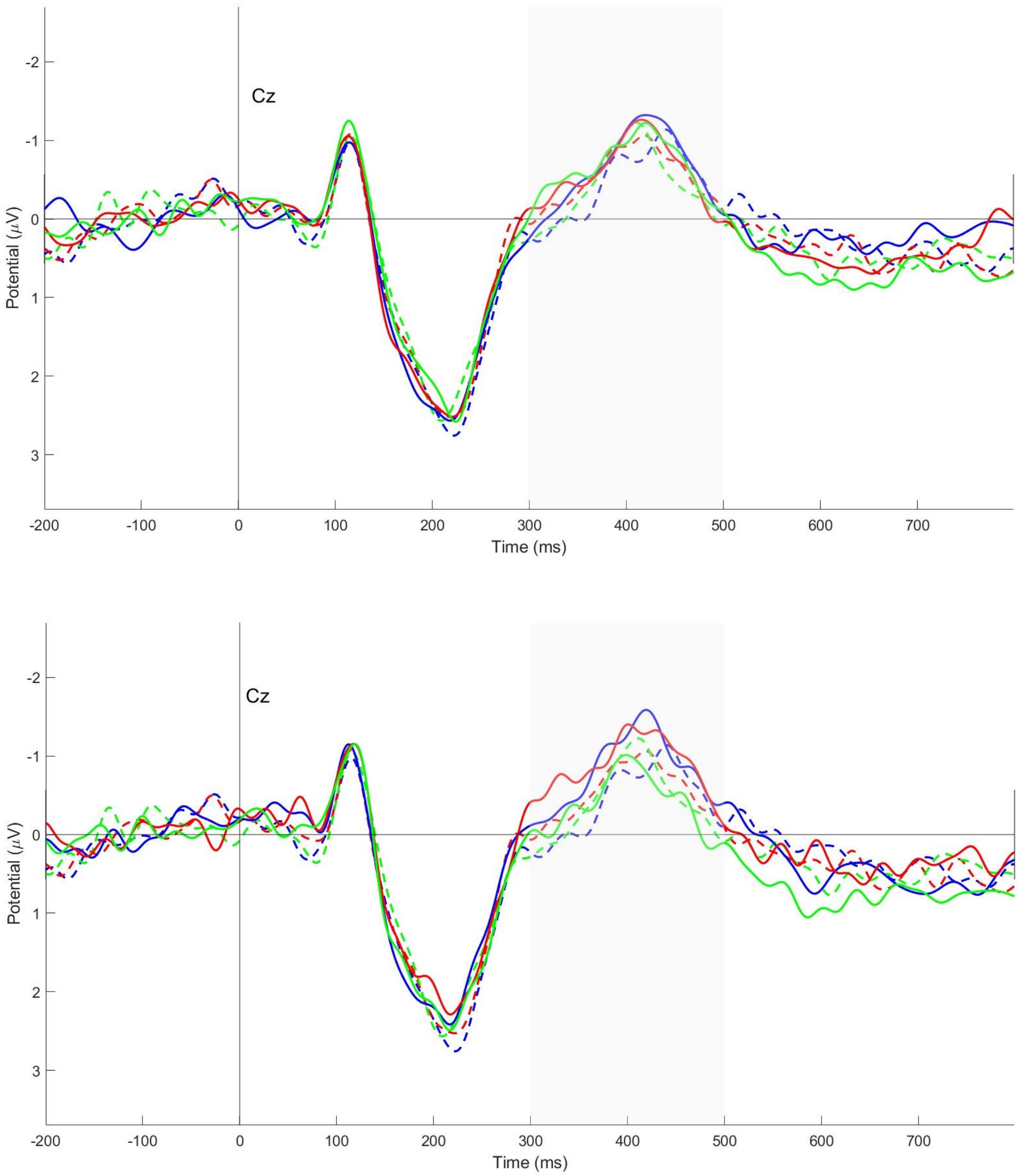


Figure 15. Averaged ERPs in a happy (top) and sad (bottom) (ERPs in solid lines) versus control (dashed lines) conditions, the N400 window (300 – 500 ms) in grey, red for positive, green for negative, blue for neutral words.

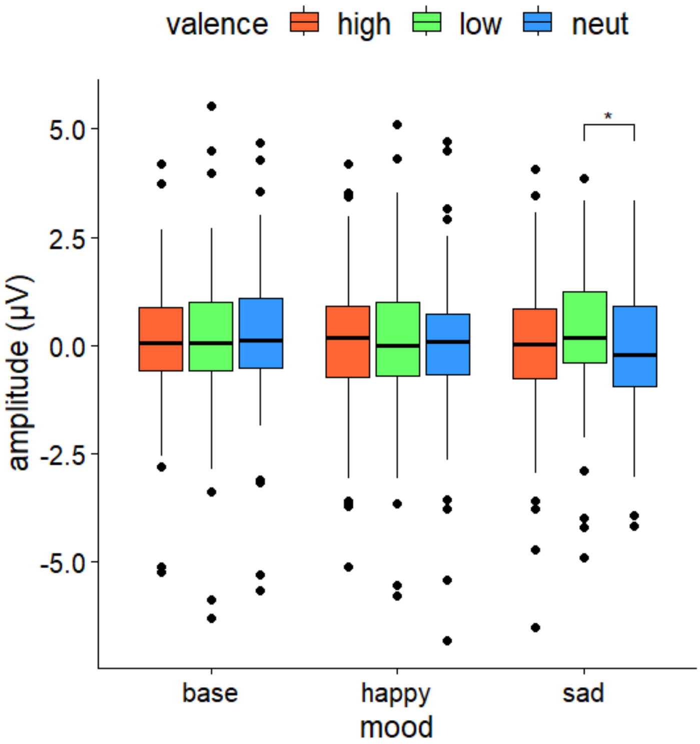


Figure 16. Distribution of N400 amplitudes across moods: control (right), happy (centre) and sad (left).

4.3.3 LPC

A three-way RM ANOVA was performed in the LPC time window (500 – 700 ms). The distribution of the data and the residuals met the assumption of normality (p > 0.1 in Shapiro-Wilk tests). *Figure 17* illustrates the distribution across conditions. The assumption of the homogeneity of variances was also met (p > 0.5 in Bartlett tests).

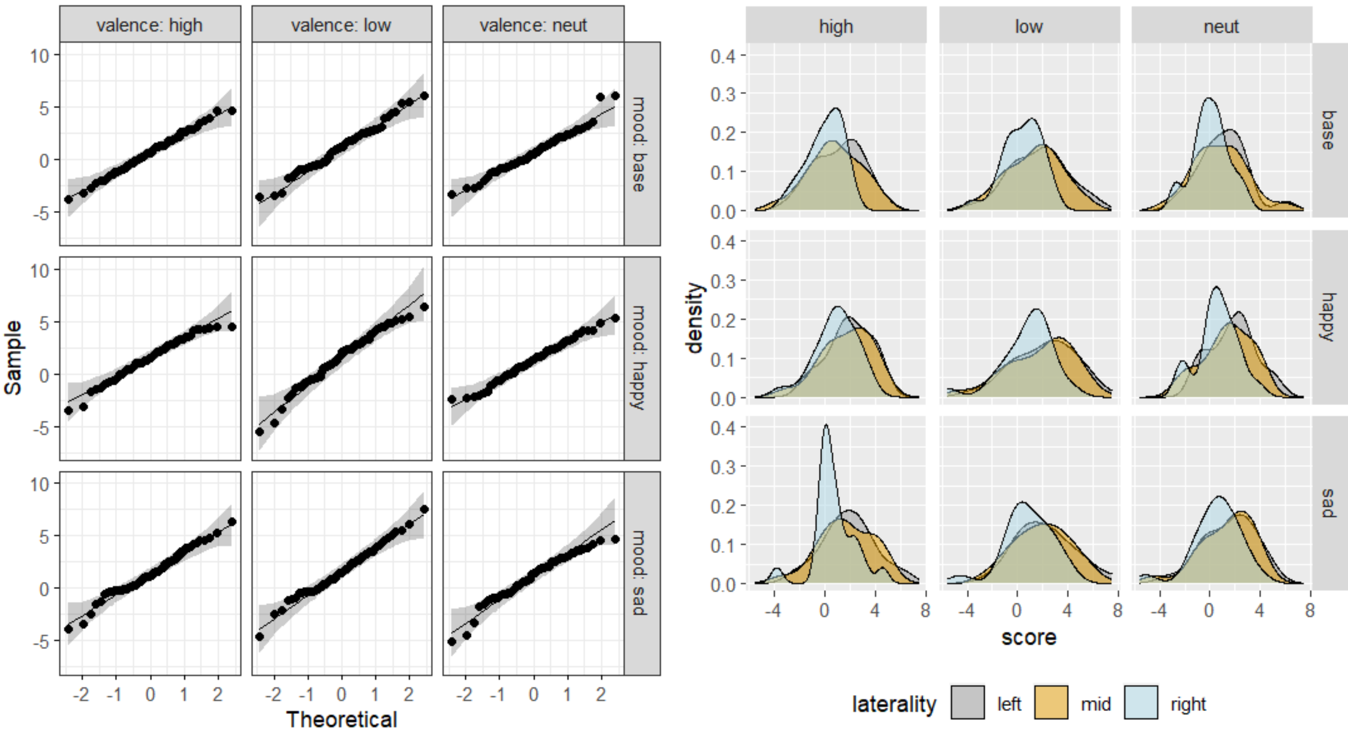
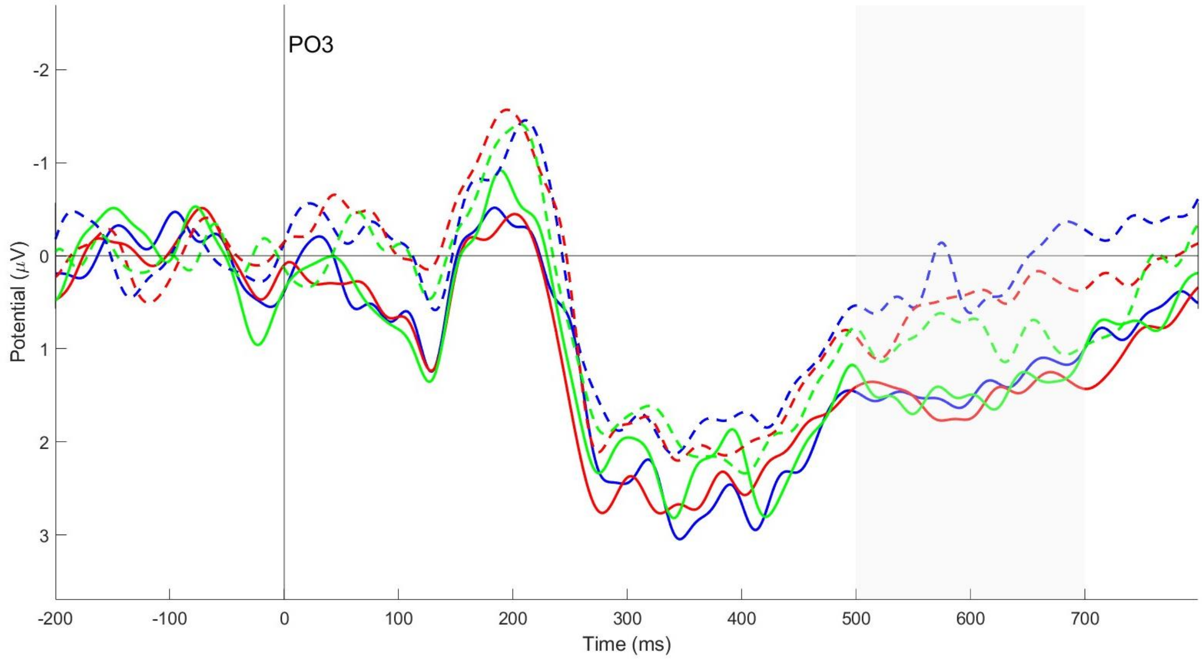


Figure 17. Quantile-quantile (q-q) plot (left) of the distribution of averaged LPC amplitudes per participant and across trials and density plot (right) of the data distribution by electrode placement: left hemisphere (grey), right hemisphere (blue) and midline (yellow).

A significant main effect of mood was found [$F(2, 34) = 9.8$, $p < 0.001$, $\eta_p^2 = 0.33$], such that positivity was greater in a happy and sad (respectively, *M = 1.44 μV, CI (0.6; 2.3*) and *M = 1.41 μV, CI (0.6; 2.2*)) rather than control mood (*M = 0.8 μV, CI (0.04; 1.6*)). Paired tests revealed a significant difference between happy and control ($t(20) = 4$, $p = 0.002$), and sad and control ($t(20) = 3.2$, $p = 0.009$) moods. *Figure 18* shows the ERPs, with happy vs control moods on top.



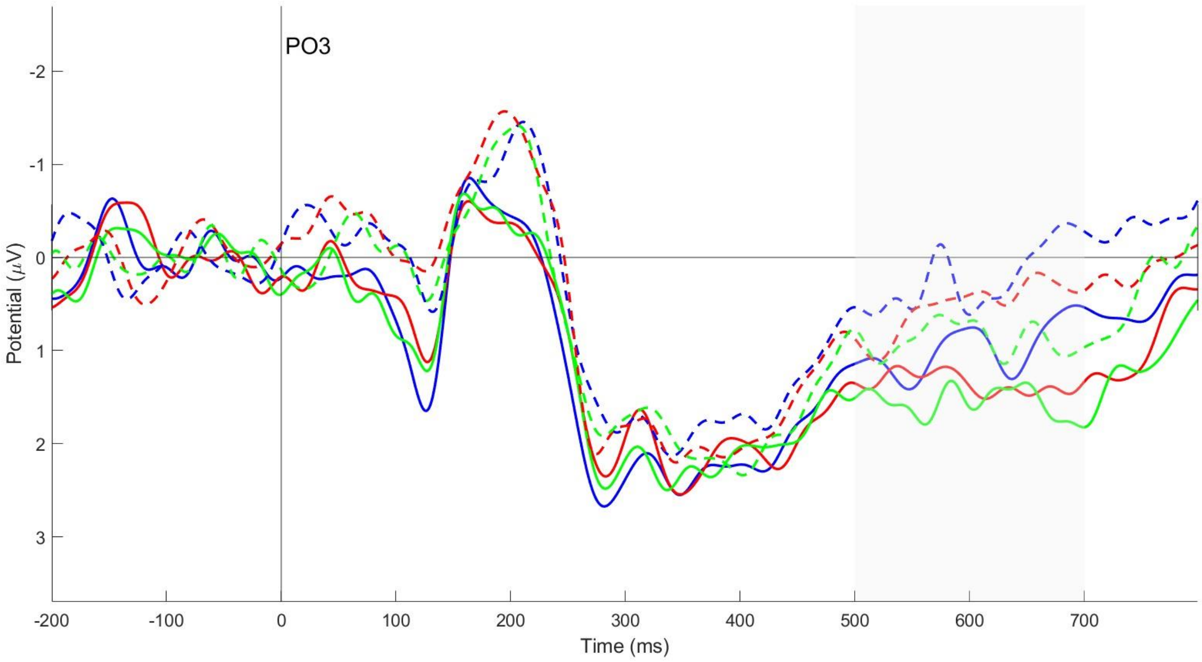


Figure 18. Averaged ERPs in a happy (top) and sad (bottom) (ERPs in solid lines) versus control (dashed lines) conditions, the LPC window (500 – 700 ms) in grey, red for positive, green for negative, blue for neutral words.

A main effect of valence was detected [$F(2, 39) = 4.5$, $p = 0.018$, $\eta_p^2 = 0.18$], with the highest LPC amplitudes for negative words (*M = 1.5 μV, CI (0.6; 2.4)*) in contrast to positive and neutral words ($M = 1.2\ \mu V$, *CI (0.4; 1.9*) and $M = 1\ \mu V$, *CI (0.3; 1.8)* respectively). The contrast between negative and neutral words was statistically significant (t(20) = 2.9, p = 0.025).

A main effect of laterality was found [F(1, 29) = 10.1, p = 0.001, $\eta_p^2 = 0.37$], with higher amplitudes over the left and midline electrode sites and lower on the right (p = 0.005). Topography across moods and word types is depicted in *Figure 19*.

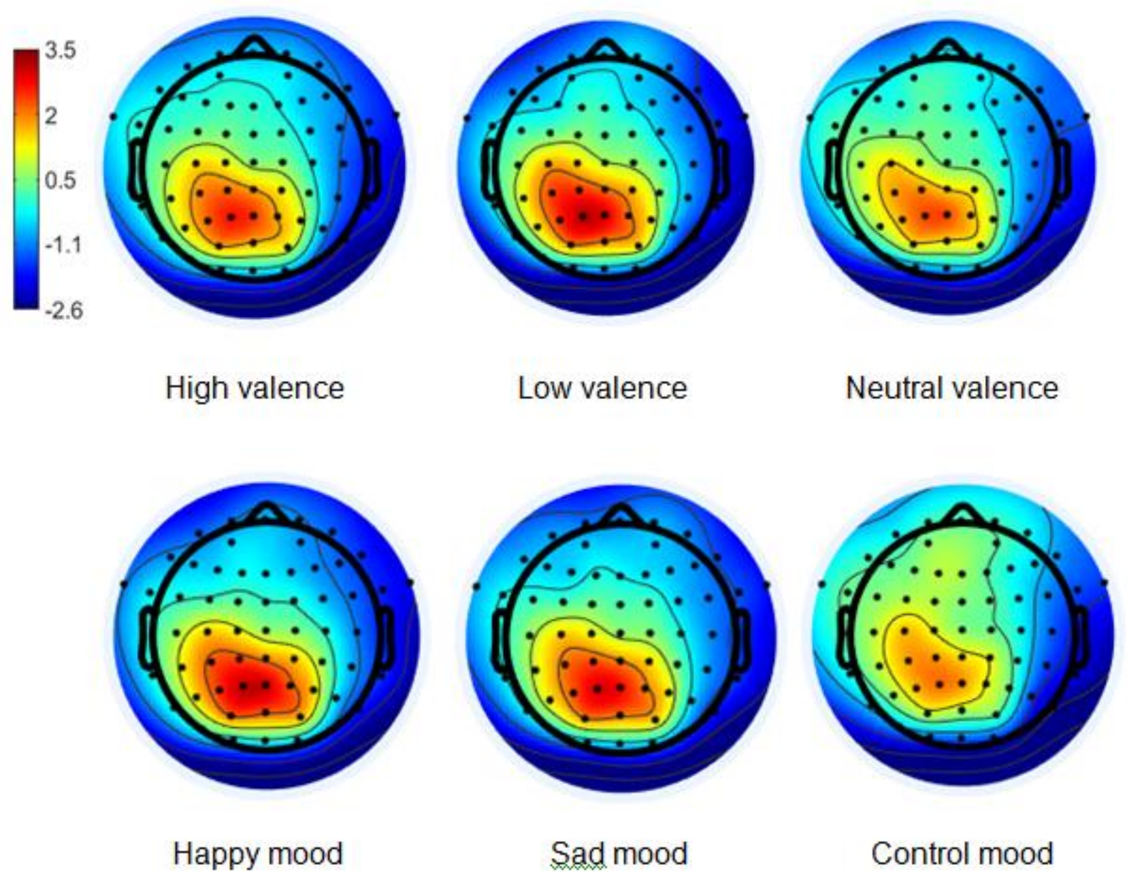


Figure 19. Topographic plots within the LPC time window (500 – 700 ms). Top row: positive (left), negative (middle) and neutral (right) words; bottom row: happy (left), sad (middle) and control (right) mood.

The RM ANOVA also revealed an interaction between valence and laterality [F(3, 59) = 3.3, p = 0.027, $\eta_p^2 = 0.14$]. LPC amplitudes were especially more pronounced over the left rather than right hemisphere for positive (t(20) = 3.3, p = 0.008) and negative (t(20) = 3.6, p = 0.003) words.

Over the left ROI, an effect of valence was found [$F(2, 40) = 6.2$, $p = 0.004$, $\eta_p^2 = 0.24$], and negative words elicited significantly higher amplitudes than neutral ones ($t(20) = 3.4$, $p = 0.009$). An effect of mood was also found [$F(2, 34) = 11.5$; $p < 0.001$, $\eta_p^2 = 0.37$], with higher amplitudes in a happy mood (*M = 2 μV, CI (1.1; 2.8))* and a sad mood (*M = 1.9 μV, CI (0.9; 2.8*)). The difference between happy mood and control and sad mood and control was significant (respectively, $t(20) = 4.6$, $p < 0.001$, and $t(20) = 3.3$, $p = 0.008$). Over the right ROI, only an effect of mood was found [$F(2, 34) = 6$, $p = 0.008$, $\eta_p^2 = 0.23$]. The pattern was similar to the left hemisphere: amplitudes were higher in a happy mood than in control ($t(20) = 3$, $p = 0.02$) and a sad mood than in control ($t(20) = 2.5$, $p = 0.04$). No interaction between mood and valence was found over either hemisphere ($p = 0.5$).

One-way ANOVAs for each mood found a main effect of valence in a sad mood [$F(2, 40) = 3.4$; $p = 0.046$, $\eta_p^2 = 0.14$]; however, paired t-tests only showed a non-significant contrast between negative and neutral words ($p = 0.052$, $t(20) = 2.6$). In the control mood, negative words elicited significantly more positivity than positive ones (respectively, *M = 1.1, CI(0.7; 2)* and *M = 0.6, CI(-0.1; 1.4);* $p = 0.045$, $t(20) = 2.7$), yet there was no effect of valence [$F(2, 40) = 3.2$, $p = 0.056$, $\eta_p^2 = 0.14$]. The contrasts illustrate an increase in the ERPs in response to positive words in the mood-induced conditions. In both a happy and sad mood, the amplitude induced by positive words differed significantly from the control ($p < 0.001$ and $p = 0.020$ respectively). Thus, mood, irrespective of being good or bad, facilitated the perception of positive words.

Overall, the effects of both valence and mood were more pronounced in the LPC window than in the EPN phase. Laterality effect was significant, with higher voltages over the left hemisphere. Negative words induced more pronounced responses across moods. ERPs in mood-induced conditions were higher than in control. ERPs were modulated by mood, but not in a congruent way. Mood significantly affected the voltages in response to positive words. While in the control mood, only negative words caused a higher response, with no difference between positive and neutral ones, in mood-induced conditions, negative and positive words together induced a higher response than neutral ones. *Figure* 20 demonstrates the difference between mood-induced and control conditions.

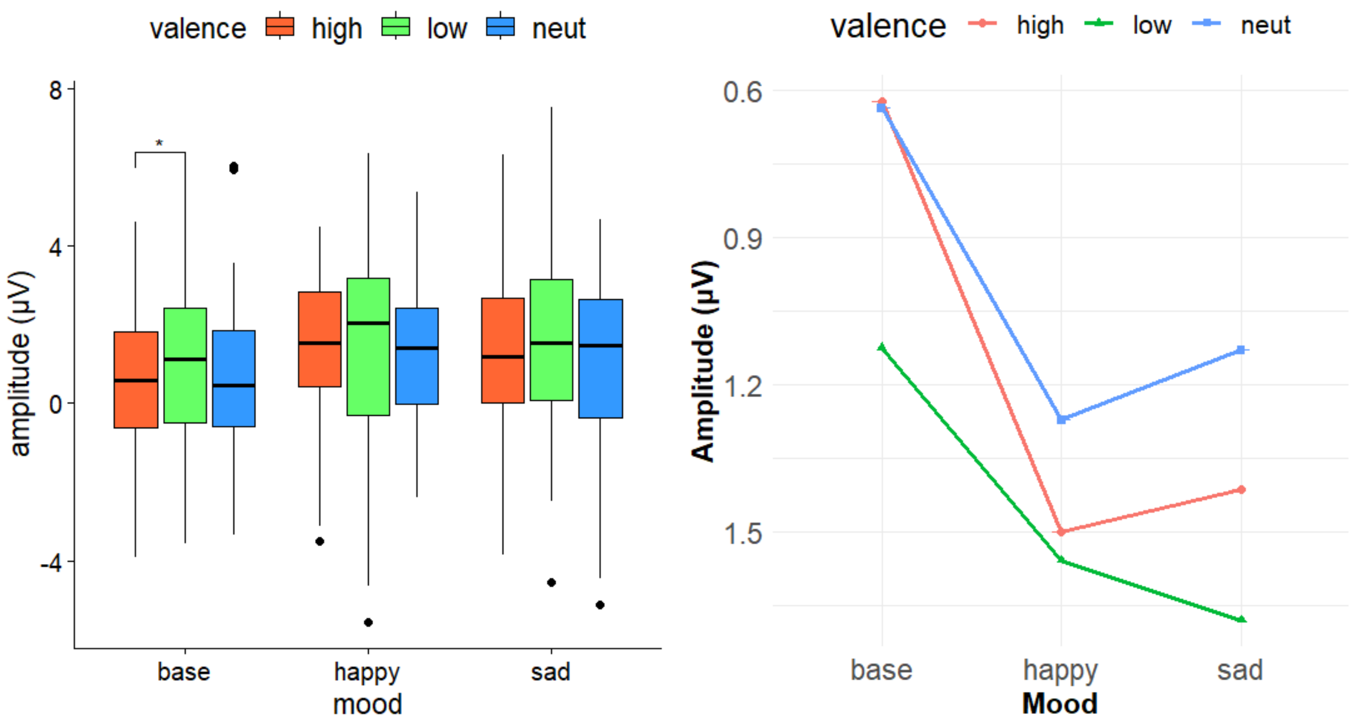


Figure 20. Distribution of the LPC data. The box plot (left) shows the distribution of LPC amplitudes across moods: control (right), happy (centre) and sad (left). The interaction plot (right) shows mean values to positive (red), negative (green) and neutral (blue) words in control, happy and sad mood.

5. Discussion

The purpose of the research presented in this thesis was to understand the effect of mood on valence during written word processing. The hypotheses were that (1) processing of emotional valence is modulated by mood, (2) these modulations occur both during automatic and reflective processing stages, and (3) congruence effects only manifest themselves in a positive mood. To test these hypotheses, an experiment was conducted where participants evaluated positive, negative and neutral words in a happy, sad and control non-mood-induced state. This chapter discusses behavioural and electrophysiological results of the experiment against the theoretical background with a focus on spreading activation and attention theories.

5.1 Summary of results

5.1.1 Reaction times

Reaction times showed a well-established emotion effect, with a speeded processing of non-neutral words, signalling motivated attention to emotional stimuli. Induced moods increased the existing advantage of emotional words, such that the difference between valenced and neutral words processing became significant. A sad mood further reduced reaction times, indicating faster disengagement from stimuli overall.

Positive words received the fastest responses in the control condition. After mood induction, they lost this advantage to negative words, pointing effects of mood on valence. However, no significant mood-congruence was found, against the predictions of spreading activation, and similar to earlier studies (e.g., Pratt & Kelly, 2008; Sereno et al., 2015). A low negative correlation between RT and attributed valence points at a slower disengagement from negative words.

5.1.2 Evaluations

Valence attributions in mood-induced conditions differed across valence groups. Evaluations of negative words were barely influenced by mood. Such resilience and accuracy can be interpreted as a high degree of focus and attention when processing negative words, and a more realistic perception of their valence. Positive words were assessed lower in a sad mood than in control. In a happy mood, the judgments were similar to the predefined valence, with no significant facilitation or inhibition. Evaluations of neutral words were skewed in the direction of mood: devoid of a strong valence of their own, neutral words received lower ratings in a sad mood than in control, and higher ratings in a happy mood than in control. This might be accounted for by the Affect-as-Information hypothesis (Schwarz, 2012), which presupposes attribution of the global valence to an individual stimulus. A positive correlation between self-reported mood ratings and attribution of valence also supports this model. However, the skew did not systematically affect positive and negative words, meaning that inherent properties of the stimulus are taken into consideration whatever the mood.

Interestingly, in the control condition, attributed ratings were consistently higher than the original ones. This might have to do with the experiment design, where the baseline condition always came first, followed by mood inductions. The participants might have felt more enthusiastic and less tired earlier in the experiment than post-induction.

5.1.3 EPN

Across moods, a valence effect was found, with more pronounced ERPs for negative words as opposed to positive ones, like in some previous studies (e.g., Imbir et al., 2015; Scott et al., 2009: Wu et al., 2021). Follow-up comparisons found that the effect was not consistently present across mood conditions. It was not found in the control, non-induced condition, in line with the majority of earlier studies of emotional words (e.g., Herbert et al., 2008; González-Villar et al., 2014, also: Citron et al., 2012). However, such an effect emerged when mood was manipulated, pointing at an interaction between mood and valence, although the interaction was not statistically significant.

In both happy and sad induced mood conditions, negative words maintained their high amplitudes. This supports the automatic vigilance hypothesis (Pratto & John, 1991), which explains a negativity bias during the perception of emotional stimuli through their potential threat. Positive words, on the contrary, were considerably facilitated in a mood-congruent manner, causing a significant difference between positive and negative words amplitudes in a happy mood. The pattern was not replicated in a sad mood, against the predictions of spreading activation. This was possibly due to slower processing in a negative mood, resulting in an offset in latency. Kiefer et al. (2007) had similar results in a memory encoding task, and suggested that valence-specific ERP effects manifest themselves later in a bad mood, after 350 ms after stimulus onset.

As expected based on earlier research (reviews in Abbassi et al., 2011; Citron, 2012; Hinojosa et al., 2020; Kotz & Paulmann, 2011), the rapid EPN effects were left-lateralised.

5.1.4 N400

The only significant finding for N400 was increased amplitudes for positive words in a sad mood, signalling higher expectations for mood-congruent words in a negative affective state. Such mood congruence does not align with the results obtained during the EPN and LPC windows, where mood-congruence was found in a happy mood. The discrepancy may be due to a large amount of outliers during N400, which made statistical analysis less credible. N400 reflects contextual integration, and the fact that the amplitude was not normally distributed may indicate that the context created by the manipulated mood was not sufficient to generate a consistent pattern of expectations across participants. This might further point at the fact that mood alone does not generate enough of a congruent semantic context for individually presented words with an equal proportion of words of different valence.

Mood-modulated changes in N400 have previously been found in studies involving sentence processing (e.g., Chwilla et al., 2011; Egidi & Nisbaum, 2012; Naranowicz et al., 2022). On the word level, Kiefer et al. (2007) found that valence effects were modulated by mood in a memorization and free recall task. This might mean that a lack of important findings is due to the nature of the task. In a design similar to the current experiment, Kissler and Bromberek-Dyzman (2021) failed to find a main effect of mood or a significant mood-valence interaction. They accounted for this by the fact that the nature of the task (evaluative decision) may have shifted the effect window onto earlier negative or later positive components.

5.1.5 LPC

Valence effect manifested itself already in the control mood, with prioritisation of negative stimuli, similar to some earlier studies (e.g., Kanske & Kotz, 2007; Wu et al., 2021; Zhang et al., 2017), supporting the automatic vigilance hypothesis (Pratto & John, 1991). In happy and sad moods, more positivity was induced by all words, signalling increased attention to stimulus properties in induced moods. Over the left hemisphere, positive words were significantly affected by induced moods, causing an increase in the LPC amplitudes in both conditions, as opposed to the control. Processed in a similar way to neutral words in control, they approached the level of negative words in a happy mood, thus rejecting the initial advantage of negative words.

The effects of mood and valence were more robust in this later window (500 – 700 ms) than during the automatic processing stage (200 – 350 ms), as expected by the task, with its explicit focus on access to lexical-semantic representations. As expected during the processing of language stimuli, valence specific perception was only prominent over the left hemisphere, despite some studies finding right laterisation during the more controlled stage of processing (e.g., Lee et al., 2022). The effect of mood was also present over the right hemisphere, although it was smaller.

5.2 Hypotheses revisited

I hypothesised that (H2) mood influences the processing of valence during both the automatic and reflective stages. During automatic processing, facilitation only occurred for positive words in a positive mood, as shown by reduced EPN amplitudes. No facilitation was found in a sad mood. During reflective processing, some facilitation occurred in both moods, as seen by increased LPC amplitudes for mood-congruent words. However, only in a positive mood, the facilitation was significant. Therefore the hypothesis was only partially corroborated, revealing facilitation across processing stages by happy moods.

Another hypothesis was that (H3) a positive mood modulates valence processing in a congruent way. As opposed to the ERP findings described above, which supported this hypothesis, behavioural measures did not point at facilitation in a happy mood, as negative rather than positive words were prioritised in a happy mood. This hypothesis was therefore partially corroborated.

Finally, while answering the overarching research question about an effect of mood on valence, I hypothesised that such an effect exists (H1). Considering the results above, this hypothesis is also partially corroborated. Support for it would have been strong if an interaction had been found between mood and valence across all ROIs. A lack of such interaction and the fact that all the three hypotheses were only partially supported points at the fact that the interaction between mood and valence is less linear than expected and requires a more detailed analysis.

Table 10. Summary of test implications by hypotheses. Filled dots indicate that the effect was found; empty dots stand for partial effect; crossed out dots stand for a lack of effect.

Hypothesis	Test implications
H1: Processing of emotional valence in words is affected by mood.	• RTs in mood-induced conditions are faster than in a neutral mood. o Attributed valence during mood-induced conditions is significantly different from the predefined valence. o There is a significant modulation of the EPN amplitudes in mood-induced conditions as compared to the control. ∅ N400 amplitudes are modulated by mood. o LPC amplitudes are modulated by mood.
H2: Mood affects valence processing both during the automatic and reflective stages of word processing.	o Mood-congruent words are facilitated in the EPN time window. o Mood-congruent words are facilitated in the N400 time window. o Mood-congruent words are facilitated in the LPC time window.
H3: Only a positive mood modulates valence perception in a congruent way.	∅ There is a mood-congruent acceleration in RTs in a positive mood. • Mood-congruent words elicit smaller EPN in a happy mood • Mood-congruent words elicit a greater LPC in a happy mood. • Mood-incongruent words elicit a greater N400 in a happy mood.

5.3 Interaction between mood and valence

The processing of all word categories in a sad mood was similar in both time windows, with increased amplitudes for negative words, followed by positive and then neutral ones. These findings go to show that in sad moods, the motivated attention and automatic vigilance hypotheses operate as they do without mood induction, resulting in prioritisation of negative words in particular and emotional words in general. The fact that the negative words received a consistent advantage across moods testifies against mood congruence during their processing. It appears that the effect of a negativity bias is too robust and strong for mood effects to counterbalance it.

Although there was no statistically significant interaction per se, there were different results for valence under different mood conditions. An interaction between mood and valence was therefore limited to positive words. Those were particularly modulated by a happy mood. During earlier processing, a mood-congruent facilitation occurred, as shown by dramatically smaller EPN amplitudes. At the later stages, however, positive words approached the pattern of negative ones, with very high amplitudes. This is especially meaningful considering that the amplitudes between the two word categories in the control mood were significantly different. The mood-congruence for positive words cannot be interpreted as an effect of spreading activation, since no similar pattern emerged for negative words. In fact, negative words showed a highly consistent pattern of processing: they were prioritised in all conditions. These findings together go to show that happy and sad moods cause qualitatively different changes in word processing.

As suggested by Kiefer et al. (2007), the difference may be rooted in the difference in adaptive strategies in the two moods that result in two completely different processing strategies. In a sad mood, accommodation takes place, which presupposes that inherent properties of incoming stimuli are perceived as they are (also supported by behavioural findings in the current study), and processing is more rigid. Happy moods are characterized by assimilation, resulting in a more open perception of incoming stimuli, when they are perceived faster and more exploratorily, with fast disengagement, and less focus on their inherent properties.

Processing of valence in different mood conditions also seems to differ depending on the processing stage. Between 200 and 350 ms, during automatic processing, positive words are discharged faster, as seen in the reduction in the EPN. The EPN can be seen as a tail of the N2 component, which signals selective attention to stimuli, and a reduction in EPN amplitude would mean faster disengagement. Between 500 and 700 ms, attention is drawn back to all stimuli due to the nature of the task, and positive words regain their advantage, as seen in a greater LPC. These effects, however, were only significant in a happy mood, and its effects appear to be more straightforward in the later, reflective stages of processing.

The difference in the components' amplitudes may also be indicative of different scalp distribution of mood and valence effects. The distribution of both valence and mood effects overlaps during later processing, as both occur in the central-parietal regions, with a left skew. In the EPN window (200 – 350 ms) the two factors appear to be differently distributed. Effects of a positive mood on valence have previously been found in a positive mood in this time window, yet over central areas, rather than the temporo-occipital region of the EPN. This leads to a confusion in the terms, with the effects being labelled as the EPN (Kissler & Bromberek-Dyzman, 2021) and as early N400 (Kiefer et al., 2007). This might indicate that the neural pathways of mood and valence, despite the two sharing the dimension of pleasantness, and modulating attention and memory processes, are different during early processing, and only align during lexical-semantic access.

6. Conclusions

The study investigated the question of whether mood fluctuations regulate the dynamics of valence processing from the stage of early lexical access to a later activation of lexico-semantic representations. The results did not yield a statistically significant interaction between the two factors. That being said, the data confirm that some modulation of valence by induced moods does take place.

Induced mood facilitated the processing of all words, and a positive mood appears to be a better facilitator than a negative mood. Congruence effects were found after happy, but not sad mood induction, against the predictions of spreading activation. This was interpreted as evidence of different processing strategies that operate in different moods. Negative moods call for more engaged and detail-oriented processing which does not alter the inherent properties of the perceived word, including its valence, as seen in more accurate evaluations and ERP data. Positive moods, on the contrary, inspire a more open and creative style of processing, which is more rapid and capable of changing the features of the stimulus. These effects were previously described for memory encoding of emotional vocabulary (Kiefer et al., 2007), but the same processes seem to apply when decoding emotional words.

Analysis of mood effects on valence during early and late processing supported the general conclusions above. Modulations of the EPN amplitudes in a mood congruent manner in a happy mood indicate a rapid automatic disengagement from the stimulus. Together with the overall trend of less negativity for all word types, this is interpreted as evidence of more superficial processing in a happy mood. A lack of mood congruence in a negative mood and the negativity bias across moods may mean that negative words retain attention during early lexical access in a consistent way. Facilitation in mood-induced conditions also occurred during the later time window of the LPC, which indicates the amount of processing resources allocated to the stimulus. Although the facilitation of positive words by moods was the strongest among all word categories, it was not strong enough to counteract the negativity bias, and the mood congruence effects in a happy mood were not sustained.

In addition to the effects of mood on emotional valence described above, the study confirmed earlier research on emotional language processing by finding emotion and valence effects. As expected, emotional words enjoyed a processing advantage over neutral ones, in line with the motivated attention hypothesis (Lang et al., 1997). This manifested itself in shorter RTs, reduced EPN and increased LPC amplitudes for positive and negative as opposed to neutral words. Valence effects were mostly present during later processing stages, as during earlier processing, such effects were only present after mood induction. A consistent advantage of negative words supports the automatic vigilance hypothesis (Pratto & John, 1991).

All in all, despite not finding a valence by mood interaction, the study supports the premise that such interaction exists but is less linear and straightforward. Happy and sad moods modulate attention in different ways, and the perception and processing of the inherent properties of stimuli, in this case emotional valence of words, is also dissimilar. This reveals a lack of clear understanding of the effects of mood on language processing, and calls for more research in this domain. Prospective avenues for further research include an investigation of the neural architecture of mood and valence, ERP research of attention modulations by mood during language processing.

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Appendix 1. Information about Participant

Information about Participant

Date________________________

Participant code (filled in by the researcher) ___________________

1. Name (First and second name) ________________________________
2. Age _______________________
3. What gender do you identify with?
    - Female
    - Male
    - Other
    - Prefer not to say

4. Have you ever had brain surgery?
    - Yes
    - No

5. Do you suffer from epilepsy?
    - Yes
    - No

6. Have you ever been diagnosed with a mood disorder (e.g., depression, bipolar disorder, dysthymia, manic episode)?
    - Yes
    - No

7. Have you ever been diagnosed with any other psychiatric disorder (e.g., borderline personality disorder, autism, ADHD)?
    - Yes
    - No

8. Have you ever been diagnosed with any neurological disorder (e.g., Parkinson's, Tourette's syndrome)?
    - Yes
    - No

Appendix 2. Edinburgh Handedness Inventory

Edinburgh Handedness Inventory Name

____

Please indicate your preferences in the use of hands in the following activities.
*Put **+** in the appropriate column.*

+ if you *usually* use this hand
+ + if you *always* use this hand

Put + in both columns if you have no preference.

Some of the activities require both hands. In these cases, indicate your preference for the object or task in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

	LEFT	RIGHT
Writing		
Drawing		
Throwing		
Scissors		
Toothbrush		
Knife (without fork)		
Spoon		
Broom (upper hand)		
Striking a match (match)		
Opening a box (lid)		
Which foot do you prefer to kick with?		
Which eye do you use when using just one?		

Appendix 3. LEAP-Q

Language Experience and Proficiency Questionnaire (LEAP-Q)

Name ____________________________

1. Please list all the languages you know **in order of dominance** (how often you use them i everyday life):

1	2	3	4	5

2. Please list all the languages you know **in order of acquisition** (your native language first):

1	2	3	4	5

3. Please list what percentage of the time you are *currently* and *on average* exposed to each language (*a total of 100%*).

Language	1	2	3	4	5
Percentage					

4. When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in a language you do not know (*a total of 100%*).

Language	1	2	3	4	5
Percentage					

5. When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of the time would you choose to speak each language? *Your percentages should add up to 100%.*

Language	1	2	3	4	5
Percentage					

6. Please name the cultures with which you identify. Please rate the extent to which you identify with each culture.

Culture:

0	1	2	3	4	5	6	7	8	9	10
No identification	Very low identification				Moderate identification					Complete identification

Culture:

0	1	2	3	4	5	6	7	8	9	10
No identification	Very low identification				Moderate identification					Complete identification

Culture:

0	1	2	3	4	5	6	7	8	9	10
No identification	Very low identification				Moderate identification					Complete identification

7. How many years of formal education do you have? ______________________________________

Please indicate your education level:

- Less than high school
- High school
- Professional training
- College
- Bachelor's
- Master's
- PhD / MD / JD
- Other: ____________________

8. If you have ever immigrated to another country, please provide the name of the country and how old you were:

____

Language: ENGLISH

This is my **native** language / **second** language / **third** language (underline).

1. Age when you…

began acquiring English	became fluent in English	began reading in English	became fluent in reading in English

2. Please list the number of years and months you spent in each language environment:

	Years	Months
A *country* where English is spoken		
A *family* where English is spoken		
A *school* where English is spoken		
A *working environment* where English is spoken		

3. Please circle your **level of proficiency** in speaking, understanding and reading in English:

Speaking

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair		Moderate		Good	Very good	Excellent	Perfect

Understanding speech

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair		Moderate		Good	Very good	Excellent	Perfect

Reading

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair		Moderate		Good	Very good	Excellent	Perfect

4. Please circle how much the following factors contributed to you learning English:

Interacting with friends

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important

Interacting with family

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important

Reading

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important

Watching TV

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important

Listening to the radio

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important

5. Please circle to what extent you are currently exposed to English in the following contexts, 0 is 'never', 10 is 'always':

Interacting with friends

0	1	2	3	4	5	6	7	8	9	10

Interacting with family

0	1	2	3	4	5	6	7	8	9	10

Watching TV / videos

0	1	2	3	4	5	6	7	8	9	10

Listening to radio / music / podcasts

0	1	2	3	4	5	6	7	8	9	10

Reading

0	1	2	3	4	5	6	7	8	9	10

Appendix 4. DASS-21

DASS-21 Name Date

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement
applied to you over the past week. There are no right or wrong answers. Do not spend too much time
on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1 I found it hard to wind down	0 1 2 3
2 I was aware of dryness of my mouth	0 1 2 3
3 I couldn't seem to experience any positive feeling at all	0 1 2 3
4 I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion)	0 1 2 3
5 I found it difficult to work up the initiative to do things	0 1 2 3
6 I tended to over-react to situations	0 1 2 3
7 I experienced trembling (eg, in the hands)	0 1 2 3
8 I felt that I was using a lot of nervous energy	0 1 2 3
9 I was worried about situations in which I might panic and make a fool of myself	0 1 2 3
10 I felt that I had nothing to look forward to	0 1 2 3
11 I found myself getting agitated	0 1 2 3
12 I found it difficult to relax	0 1 2 3
13 I felt down-hearted and blue	0 1 2 3
14 I was intolerant of anything that kept me from getting on with what I was doing	0 1 2 3
15 I felt I was close to panic	0 1 2 3
16 I was unable to become enthusiastic about anything	0 1 2 3
17 I felt I wasn't worth much as a person	0 1 2 3
18 I felt that I was rather touchy	0 1 2 3
19 I was aware of the action of my heart in the absence of physical exertion (e.g., sense of heart rate increase, heart missing a beat)	0 1 2 3
20 I felt scared without any good reason	0 1 2 3
21 I felt that life was meaningless	0 1 2 3

Appendix 5. PANAS

PANAS Name ________________________
Positive and negative affect scale

This scale consists of a number of words that describe different feelings and emotions. Rate each item and indicate to what extent you felt like this in the previous week. Mark your answer in the space next to the word. Use the following scale to record your answers:

1 = Very slightly or not at all
2 = A little
3 = Moderately
4 = Quite a bit
5 = Extremely

Interested	______	Irritable	______
Distressed	______	Alert	______
Excited	______	Ashamed	______
Upset	______	Inspired	______
Strong	______	Nervous	______
Guilty	______	Determined	______
Scared	______	Attentive	______
Hostile	______	Jittery	______
Enthusiastic	______	Active	______
Proud	______	Afraid	______

Appendix 6. Participant Information Sheet

LUND UNIVERSITY

Participant Information Sheet

You are invited to participate in the study "*Emotions and Language Judgments*". Below you find detailed information about the study. Please familiarise yourself with the text.

What kind of study is it and why do you want me to participate?

The purpose of the study is to investigate how people make judgments about words. Previous research has shown that judgments about words differ depending on context, and that several factors contribute to how a word is perceived. One of these factors is how we feel when we read words. How we feel determines how we behave and think in general, and it also affects how our brain processes language. It is interesting to examine how native speakers make judgments about words as their emotions change. This can further contribute to a greater understanding of the general mechanisms according to which the brain processes language. We investigate these processes in English and you, as a native speaker of English, are specifically asked to participate in the study.

How does the study work?

The study includes a reading experiment that is carried out during one day in the Humanities Lab at Lund University. Before you come to the experiment, we ask you to wash and comb your hair. Please do not use any conditioner.

During the experiment, electroencephalography (EEG) will be used to measure changes in the electrical voltage that, due to brain activity, is always present on the head. To do this, an electrode cap is placed on your head and a few separate electrodes are carefully attached to the skin behind the ears, on the forehead and on the cheek. This is necessary to record your brain activity through measurements of the voltages that naturally exist on the head.

Before putting any electrodes on, we will wipe them with alcohol to make better contact with the skin. We will then put the electrode cap on your head. To get a good contact, we will inject a conductive gel between the head and the electrodes and touch the scalp a little with small wooden sticks to ensure good signal transmission. Attaching the electrodes takes 60 minutes.

While the electrodes are being placed, you will be asked to fill in several questionnaires: one regarding your language background, one regarding your handedness (right/left handed), two regarding your mood during the week before the experiment and one regarding your current mood, and a questionnaire where you will be asked whether you have had any previous brain injuries, have been diagnosed with unspecified mood disorders or neurological disorders.

There are three parts to the experiment itself. First, you will be shown English words on the screen in front of you. Your task is to evaluate the words. A short practice session precedes the experiment so that you could familiarise yourself with the task. The first part of the experiment takes about 6 minutes. You will be given the opportunity to take short breaks in the middle of the experiment if you wish.

During the second and third parts, you will first get to look at images on the screen. Several images are of a deeply emotional nature and may be perceived as triggering. They depict scenes of violence, crime, injuries, dangerous animals and natural disasters. You will be asked to focus on each image for 5 seconds. There will be 60 images in each part, but they will be presented in blocks of 20. If the images make you feel severely uncomfortable and you no longer wish to participate, you may cancel your participation. You do not have to state why. After each block you will evaluate words as in part one. The second and third parts will take about 11 minutes each.

When the experiment is finished, you can ask us questions about the experiment. After the experiment, the cap is removed and you can shower off the gel. Cap removal usually takes about 5 minutes. The whole of the experiment will take 2 hours.

Possible consequences and risks of participating in the study

There is a small risk that some people may experience discomfort in front of the equipment. If you feel uncomfortable, we will interrupt the study. You can withdraw from participating in the study at any time without having to give any reasons and without any consequences whatsoever.

You will be asked in a form if you have had a previous brain injury, unspecified mood disorders or neurological disorders. You will also fill out a relatively detailed language background form. It can in principle be used to infer your ethnic origin. The forms will only be used to guarantee the homogeneity of the group. They will be kept in a binder in a locked room until all the data are encoded, after which the forms will be destroyed.

What happens to my data?

The study will collect and record information about you. In the first experiment, we will measure your brain waves through EEG to see how your brain processes language. These data will primarily be analysed at the group level together with other people's results. The EEG data will be stored in an encoded form on a server to which only the project investigators have access. To analyse the correlation between the data in the first, second and third parts of the experiment, comparisons will be made across participants completely anonymously. Brain waves from individual participants will not be reported, only the calculations about the effects under study.

The information collected from the questionnaire where you describe your language background, e.g. which languages you have learned and where you have lived growing up will only be reported at aggregated group level. This is to show that those who participated in the study have a relevant language background. To assess the degree to which you are right-/left-handed, you will also have to answer some questions about which hand you use with different objects and for different activities. This information will, to the extent that it is reported, be reported as a compilation at group level to demonstrate the homogeneity of the group. The same applies to any information collected regarding your mood before the experiment.

No information you share will be traceable to specific individuals. Individual-related information will only be available to the experimenter and the project manager. Information collected in paper form will be digitised in pseudonymised form and then kept locked in the project manager's room. The code key for the pseudonymisation will be stored separately, also locked in the project manager's office. All paper forms with the associated code will be destroyed no later than two years after participation in the study. In order to be able to check data afterwards and carry out further data analysis if necessary, all digital information and data will be saved as long as it is possible to ensure that these are inaccessible to unauthorised persons. There is the possibility that pseudonymised data may subsequently be posted on a publicly available database. This will only be done after the original paper form and the code key have been destroyed.

Your answers and your results will be processed so that unauthorised persons cannot access them. Lund University is responsible for your personal data. According to the EU's data protection regulation, you have the right to access the information about you that is handled in the study free of charge, and if necessary to have any errors corrected. You can also request that information about you be deleted and that the processing of your personal data be restricted. However, the right to erase and to limit the processing of personal data does not apply when the data are necessary for the current research. If you want to access the information, please contact *Johan Blomberg, visiting address: SOL-centrum, Helgonabacken 12; postal address: SOL-centrum, Lund University, Box 201, 22100 Lund; e-mail: johan.blomberg@ling.lu.se; phone 046–2229902*. The Data Protection Officer can be reached at *dataskyddombud@lu.se*. If you are dissatisfied with the way your personal data is processed, you have the right to file a complaint with the Swedish Data Protection Authority, which is the supervisory authority.

How do I get information about the results of the study?

The results of the study will be published in a master's thesis and possibly an open access article. The results of the pilot are not included in the main paper but serve the function of ensuring the correct set-up for the experiment. Feel free to contact the experimenter or project manager at least 6 months after participation if you want to know more. To share your individual results, you can also get in touch. However, it is important to bear in mind that individual data from the EEG are very difficult to interpret. It is also important to understand that the study is not a diagnostic test or medical examination and the experimenters and project leader do not possess the means or expertise to detect or inform about any medical conditions or abnormalities detected. The nature of the experiment is limited to studying the brain’s processing of vocabulary items.

Insurance and compensation

During your participation, you are covered by an insurance for special personal injury protection, *“Särskilt personskadeskydd”,* by the Humanities Lab. The insurance is renewed every year. The current insurance number is 28.3.1-089556-2019-15. Your compensation for participation is a cinema gift ticket that will be emailed to you after participation.

Participation is voluntary

Your participation is voluntary and you can choose to withdraw from participating at any time. If you choose not to participate, you do not need to state why, and it will not affect your future treatment. If you wish to cancel your participation, please contact the person responsible for the study or the experimenter.

Responsible for the study

The person responsible for the study is Johan Blomberg, visiting address: SOL-centrum, Helgonabacken 12, postal address: SOL-centrum, Lund University, Box 201, 22100 Lund, e-mail: johan.blomberg@ling.lu.se, phone 046–2229902. The experimenter is Ekaterina Kopaeva, e-mail: el1445ko-s@student.lu.se

Consent to participate in the study

- I have received oral and written information about the study and have had the opportunity to ask questions. I get to keep the written information.
- I agree to participate in the study "*Emotions and Language Judgments*"

Place and date______________________ Signature ______________________________

Full name ______________________________

Appendix 7. Verbal stimuli

Neutral valence			**High valence**			**Low valence**		
absurd	hand	poetry	ace	diploma	muscular	abortion	frigid	penalty
activate	haphazard	privacy	advantage	dream	music	ache	funeral	pest
alien	hard	python	agreement	earth	nature	allergy	fungus	poison
alley	hawk	rancid	ambition	easy	ocean	alone	gangrene	poverty
aloof	heroin	rattle	angel	elegant	outdoors	beggar	garbage	prison
anxious	hide	razor	applause	enjoyment	palace	blind	germs	rabies
appliance	highway	reptile	art	family	paradise	blister	gossip	rat
army	history	revolt	astronaut	fantasy	pasta	broken	grief	robber
avenue	hit	revolver	bath	flower	patriot	bullet	headache	rotten
bathroom	hospital	rifle	beauty	free	perfume	burial	hell	sad
beast	humble	rough	beverage	friendly	pizza	carcass	helpless	scandal
body	industry	runner	bless	garden	present	coffin	hooker	scar
boxer	insolent	salute	bliss	girl	puppy	corpse	hurt	scum
cane	invest	scissors	blossom	glamour	rabbit	corrupt	idiot	scurvy
cannon	journal	sentiment	blue	grateful	radio	coward	ignorance	severe
cellar	kerosene	serious	bouquet	greet	rainbow	crime	illness	shamed
chaos	kick	shadow	breeze	grin	respect	criminal	immature	sick
cliff	lion	sheltered	bride	handsome	reward	crisis	immoral	slime
clumsy	lump	ship	brother	home	river	crude	infection	slum
coarse	manner	shotgun	bunny	honey	sapphire	cruel	injury	smallpox
coast	medicine	skull	cake	hug	satisfied	crushed	insane	spider
cold	mischief	spray	candy	humane	savior	damage	invader	starving
contents	modest	stagnant	capable	humour	scholar	dead	jail	stench
context	moment	stiff	carefree	infant	sky	death	lawsuit	stink
custom	muddy	storm	caress	innocent	snow	debt	lice	stupid
dark	mushroom	stove	charm	inspire	snuggle	defeated	lonely	suicide
defiant	name	tamper	chocolate	intellect	social	deformed	loser	tobacco
dentist	neurotic	tank	christmas	jewel	soft	delayed	maggot	tomb
derelict	news	teacher	colour	jolly	soothe	depressed	manure	torture
detail	noisy	tease	crown	kind	spouse	dirty	massacre	traitor
doctor	nonsense	theory	cuddle	king	spring	dummy	measles	trash
embattled	nursery	tool	cuisine	kitten	sun	dump	misery	ugly
errand	obey	truck	cute	letter	swimmer	failure	mistake	unhappy
excuse	obscene	trumpet	daylight	liberty	tender	fat	moody	urine
fabric	obsession	vanity	decorate	lively	toy	fault	morbid	useless
farm	odd	volcano	delight	loyal	trophy	feeble	morgue	venom
frog	part	whistle	devoted	luscious	truth	fever	mosquito	victim
gender	passage	wine	diamond	luxury	vacation	filth	neglect	vomit
habit	phase	writer	dignified	melody	wink	flood	nuisance	wasp
hammer	pistol	yellow	dinner	movie	yacht	foul	obnoxious	waste