

# The role of valence and origin of emotions in emotional categorization task for words

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## ABSTRACT

Emotional meaning of words can be defined in terms of a few factors, including traditionally investigated valence and arousal, as well as recently proposed emotional origin. The emotional origin is a dimension spanned by the concepts of automatic vs. reflective emergence of an emotion. This article presents the results of an investigation focused on the role of valence and emotional origin of word connotations for moderately arousing verbal stimuli for performance in emotional categorization task. The task for participants was to assess whether a given word has for them an emotional meaning. Behavioral results showed a higher proportion of words indicated as emotional for both negative and positive in comparison to neutral stimuli as well as for stimuli inducing automatic originated emotion, as compared to other groups. ERP amplitude differences, localized in specific regions were, observed for valence and origin in 250–690 ms time range. Effects of origin were found earlier in time in comparison to the effects of valence. The novelty of this study is that it demonstrates that the origin of emotion, besides the well-known valence, is a significant factor for the processing of words in an emotional categorization task.

## 1. Introduction

The study of emotional word processing gives us an insight into two different aspects of mental functioning: word processing and affect structure (Briesemeister, Kuchinke, & Jacobs, 2014; Citron, 2012; Delaney-Busch, Wilkie, & Kuperberg, 2016). Because debate over the mechanisms underlying emotion formation is still ongoing (Kagan, 2007), it is important to answer the question: which aspects of an affect influence the way we perceive emotional words (Citron, 2012; Citron, Weekes, & Ferstl, 2013)? Since there are different approaches to an affect structure, this paper investigates whether the newly proposed dimension, namely the origin of an affective state (Imbir, 2015; Jarymowicz, 2012; Jarymowicz & Imbir, 2015), is an important factor in the recognition of words emotional load.

### 1.1. Models of affect: dimensions describing emotionality

The structure of an affect is still an open question in affective sciences (Frijda, 2007; Kagan, 2007; Russell, 2003). There are two competing approaches in the field. The first is focused on investigation of emotions treated categorically (e.g. happiness, joy, sorrow,

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basic emotions, self-conscious emotions etc.). In such an approach, for example, effects of one emotion (like pride) are the main point of interest (Williams & DeSteno, 2008). The second is aimed at searching for dimensions underlying emotional processes (Imbir, 2015; Russell, 2003, 2009). For example, valence, arousal, and dominance were found with the use of semantic differential to be dimensions that explained most of the variance in emotional reactions to stimuli (Lang, 1980; Lang, Bradley, & Cuthbert, 1997; Osgood, Suci, & Tannenbaum, 1957). Russell (2003) treated valence and arousal as dimensions defining the affective space of current emotional states. Such affective states can be characterized as either moods or emotional episodes (Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Russell, 2009).

Recently a new approach to emotional diversity, the emotion duality model, was proposed (Jarymowicz, 2012; Jarymowicz & Imbir, 2015). In addition to valence, this model points that the origin of an affective state is also a factor that plays an important role in the diversity of human emotional experiences. The origin of an affective state is an important determinant of whether automatic vs. controlled mechanisms (Epstein, 2003; Kahneman, 2011; Reykowski, 1989; Strack & Deutsch, 2004, 2014) are involved in emotion formation. To put it simply, joy may be on the one hand a result of eating something tasty (sweet), but on the other hand, the result of achieving something important (fulfilling our expectations toward ourselves). In the first case, emotional experience is derived from an automatic reaction to sweetness, based on so called biological value (Damasio, 2010). In the context of biological value everything helpful to maintaining life is evaluated positively (e.g. caloric food), while threats to life are evaluated negatively (rotten and smelly, poisonous food). In the second case, emotional experience is the result of controlled and reflective processing (Strack & Deutsch, 2004) based on an appraisal of the current situation in the context of our own standards of evaluation (Jarymowicz, 2012; Reykowski, 1989). Such a mechanism is reflective in nature. Similarly, healthy food that does not taste good may, despite the automatic reaction evoked by an unpleasant taste, evoke joy due to fulfillment of our aims, such as dieting in order to maintain fitness.

The origin factor was operationalised recently with the Self-Assessment Manikin (SAM) scale (Imbir, 2015; 2016a), allowing for assessing subjectively perceived degree of automatic vs. reflective originated process engagement in affective reactions to stimuli (c.f. Fig. 1). The origin scale was created on the basis of a heart vs. mind opposition metaphor, a well-known symbol representing dual mental processes (Jarymowicz, 2012; Kahneman, 2011) (automatic vs. controlled). Heart represents automatic affective reaction formation due to immediate impulses and reactions toward external situations. Mind represents reflective thinking (Strack & Deutsch, 2004) and appraisal of reality (Reykowski, 1989), leading to more deliberate emotional reactions. The origin SAM scale was used in order to evaluate affective reactions to words (Imbir, 2016a), short texts (Imbir, 2017a) and music fragments (Imbir & Gołab, 2017), each time showing high reliability in assessments, namely high stability of participants' assessments of their reactions. The correlation of evaluation of origin with evaluations of other variables was studied (c.f. results in Imbir 2016 ANPW\_R). Origin is in fact correlated with other factors, but those relations are not strong. For Nouns only, the correlation values ( $r$ ,  $p$ ) are: Valence (0.04, .03); Arousal (0.44, .001); Significance (0.29, .001); Concreteness (0.32, .001); Dominance (0.22, .001); Logarithm of frequency of appearance ( $-0.01$ , .59); Imageability (0.06, .001) and Age of acquisition (0.02, .26). Origin shares no more than .2 common variance ( $r^2$ ) with other affective dimensions.

From those results, we concluded that origin is a well-measured factor worth further investigation in order to identify its role in cognitive functioning (Imbir, 2016b; 2017d; 2017b).

Apart from the methodological and measurement issues, we have to state at the beginning, that both automatic and reflective originated emotions differ in the default operating mode (Jarymowicz, 2012; Jarymowicz & Imbir, 2015). Verbalization is primarily specific for reflective emotions and in the broader sense the so-called reflective mind (Strack & Deutsch, 2004), while figurative representations are specific for automatic emotions and in a wider sense for the so-called experiential mind (Epstein, 2003; Imbir, 2016b). It does not imply that words cannot represent automatic states, like words pain or disgust does. This implies that labels for automatic emotions do so in a secondary way. This means, a word should be earlier decoded and understood, only then it evokes

The first picture shows an individual who is overwhelmed with appeals from the heart – words that could represent these experiences include being beside oneself, complete commitment, full engagement, impulsivity, spontaneity, lack of hesitation. The last picture shows a person who is under the sway of the mind, which is reflective – words that could be used to represent this state include feelings that result from contemplation, planning, consideration, prediction, choices, or comparisons

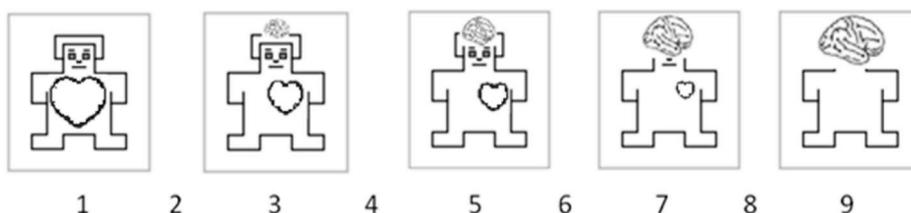


Fig. 1. SAM scale and dimensions description developed for origin of an affective reaction to stimuli measure (Imbir, 2015).

associations characteristic to automatic origin. The opposite situation, when searching for figurative representations of reflective emotions is far more challenging, i.e. few pictures are existing, that represent the clear reflective states like pride or contempt unambiguously. Taking this into account, words are stimuli that can easier represent reflective states, but it is important to differentiate two things: (1) the word processing and decoding of meaning and (2) the affective information processing and influence of this information on the word processing itself, since both are close in time.

It is also worth to discuss further issues concerning the origin concept. The origin of emotion might be part of the semantic feature of words (Mitchell, Malave, Shinkareva, & Mason, 2008). The representation of reflective words might have more divergent and complex semantic features and might have more individual differences due to differences of life experience, belief, political characteristics and moral valuation (Jarymowicz, 2012; Jarymowicz & Imbir, 2015). This is coherent with the definition of the origin and may be treated as the potential limitation.

The reflective originated words might also be different from automatic words in their connectivity in the semantic network (De Deyne, Kenett, Anaki, Faust, & Navarro, 2017). Words with automatic origin associations could also be processed more in an embodied way (Niedenthal, 2007), or they may be closer to the proposed basic emotions (Johnson-laird & Oatley, 1989).

## 1.2. Emotional word processing stages and factors influencing this process

Processing of word stimuli while reading is quite a complicated mechanism. It involves several stages, including: (1) early processes associated with perception of graphical signs, letter recognition, syllables and word percept formation that all have the visual and attentional base; (2) the lexico-semantic processes providing an individual with access to the stimulus meaning, and finally (3) late stages of post-semantic processing involving associations elicited by the meaning of a certain stimulus (Jończyk, 2016). The initial early processes may be affected by the visual or graphical features of verbal stimuli, therefore are far less interesting in studies concerning emotional words processing. Nevertheless an attention modulation by the affective state of an individual can be observed. For example, negative emotions were found to drive attention toward the source of the threat (Ohman & Mineka, 2001). Also, verbal sources of affect were found to influence the initial word processing (Hofmann, Kuchinke, Tamm, Vö, & Jacobs, 2009; Kissler, Herbert, Winkler, & Junghofer, 2009a; Zhang et al., 2014). In the later stages, we have to deal with two distinct modulations of word processing. The first one is caused by the emotionality of stimuli, while the second by the semantic associations with a certain stimulus. For example, the negative word representing a threat can influence the mind through its negative valence or through the semantic associations of the threat. From that reason, it is particularly hard to differentiate the effects. The studies concerning electrophysiological correlates of emotional words processing may give us an insight into the nature of the described above effects.

When considering electrophysiological correlates of word processing, the effects of emotions on patterns of neural activity were found at several stages, i.e., early components such as early waves or Early Posterior Negativity (EPN) and late components, such as P3 or the Late Positive Complex (LPC) (Citron, 2012). Early components include differences found in several different time ranges: (1) around 100 ms post-stimulus (Hofmann et al., 2009; Ortigue et al., 2004; Smith et al., 2006); (2) in the N1 time period (Bernat, Bunce, & Shevrin, 2001; Briesemeister et al., 2014; Hinojosa, Méndez-Bértolo, & Pozo, 2010; Hofmann et al., 2009; Kissler & Herbert, 2013; Scott, O'Donnell, Leuthold, & Sereno, 2009; Wang, Bastiaansen, Yang, & Hagoort, 2013); and (3) in the P2 time period (González-Villar, Triñanes, Zurrón, & Carrillo-de-la-Peña, 2014; Herbert, Kissler, Junghofer, Peyk, & Rockstroh, 2006; Kanske & Kotz, 2007; Ortigue et al., 2004; Thomas, Johnstone, & Gonsalvez, 2007; Wang et al., 2013). (4) EPN is a negative going wave that shows up in the temporal and occipital electrodes around latency 200–400 ms and has a higher amplitude for positive and negative words than for emotionally neutral words (Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Peyk, & Junghofer, 2007; Kissler, Herbert, Winkler, & Junghofer, 2009b; Schacht & Sommer, 2009b, 2009a). (5) The N450 component is a negative going wave that shows up in the fronto-central locations at about 350–500 ms after stimulus onset (Imbir, Spustek, Duda, Bernatowicz, & Zygierewicz, 2017b; West & Alain, 2000). The N450 amplitude indexes the conflict detection (West, 2003; West & Alain, 2000) and was found to be greater on incongruent than congruent trials of Stroop test. Finally (6) the P3 or (7) the LPC components were identified in the time period starting from 300 ms (P3) or about 400–500 ms (LPC) (Citron, 2012; Fischler & Bradley, 2006; Gable, Adams, & Proudfit, 2015; Hajcak, MacNamara, & Olvet, 2010; Kissler, Assadollahi, & Herbert, 2006). The P3 and LPC component family is a positive deflection of the event-related potentials observed at the central and parietal sites. On the one hand, an increase in LPC amplitudes has been shown for emotional words in comparison to neutral ones (Citron, 2012; Fischler & Bradley, 2006; Herbert et al., 2006; Schacht & Sommer, 2009b). On the other hand, LPC amplitude was found to be larger (Ito, Larsen, Smith, & Cacioppo, 1998) and/or longer (Hajcak & Olvet, 2008) in response to unpleasant than pleasant stimuli (when levels of arousal were matched across experimental conditions).

More recent research has shown, that the nature of the task people are performing makes a substantial contribution to how valence and arousal modulate LPC amplitude (Delaney-Busch et al., 2016). When participants performed an overt valence categorization task, the LPC was shown to be susceptible to valence differences in stimuli (with unpleasant words eliciting the most positive deflection in LPC), but there was no effect of arousal. In contrast, when participants were asked to perform a task not directly relevant to emotionality, such as a semantic categorization task, the LPC showed a larger amplitude for high-arousing words than low-arousing words and no differences that could be attributed to valence.

Event-related potential components described above are hypothesized to be manifestations of three stages of emotional word processing (Zhang et al., 2014), respectively: (1) the early time ranges at occipital regions are supposed to be attentional correlates of visual word processing, (2) the EPN time range is expected to reflect the emotional/non-emotional discrimination stage of word processing based on lexico-semantic processing, and (3) in the LPC time range the post-semantic processing of stimulus meaning is expected (Jończyk, 2016), including specific differentiation between distinct valences (Zhang et al., 2014) as well as activation of

word meaning associated knowledge (Strack & Deutsch, 2004). The N450 component also may be treated as a manifestation of the semantic access, since the N450 was found to be susceptible to the inconsistencies in word meaning (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Imbir, Spustek, Bernatowicz, Duda, & Żygierewicz, 2017a; Imbir, Spustek, Duda, et al., 2017b; Kutas & Federmeier, 2011).

### 1.3. Origin of an affective state in word processing

Origin of an affective state represented in word meaning connotations (Imbir, 2016a) appeared to be a factor that shaped cognitive consequences of emotions measured in behavioral paradigms (Imbir, 2017b, 2017c) and electrophysiological correlates of involuntary word processing (Imbir, Spustek, Duda, et al., 2017b; Imbir, Spustek, & Żygierewicz, 2016). Considering behavioral paradigms, it appeared that word presentation may alter the way a subsequent task is processed in a direction predicted in the dual mind emotion-cognition interactions model (Imbir, 2016b). For example, choosing one of two signs better symbolizing reflective originated words took more time than the same task performed for automatic originated words (Antosz & Imbir, 2017; Imbir, 2017d). In another study, task for participants was to guess the meaning of an ambiguous stimuli taken from a far east pictorial alphabet (they were instructed that signs represent personality traits) in terms of their relation to warmth and competence fundamental dimensions of social cognition. The emotional word was displayed before each sign, and the additional task for participants was to keep this word in mind for a while. It appeared that positive reflective originated words primed the interpretation of ambiguous stimuli in terms of competence related rather than warmth (Imbir, 2017b).

Implicit word meaning processing observed in the Lexical Decision Task (Imbir et al., 2016) as well as in the emotional Stroop task (Imbir, Spustek, Duda, et al., 2017b) was also found susceptible to the differences in the emotional origin of words. In both studies, the origin affected amplitudes of evoked potentials in the FN400 (Lexical Decision Task: LDT) or N450 (in Emotional Stroop Task: EST) as well as LPC components. In the LDT paradigm, the task for participants was to differentiate between words and pseudo-word stimuli. Each time they had to decide whether the stimulus is an actual word or not. The differences observed in the LDT paradigm study were associated with certain ROIs (right-frontal and left-parietal). Amplitudes for automatic originated stimuli were the most negative in the right-frontal ROI, while automatic and reflective originated words elicited more positive amplitudes than control words (mixed or unspecified origin, c.f. method section) in the left-parietal ROI. In the EST paradigm study the task for participants was to name the color of the font of an emotional word while ignoring the meaning of the word. Differences were found to be generally distributed over all ROIs. Particularly, reflective words elicited less negative (N450 component) and more positive (LPC component) activity than automatic originated words.

Origin of an affective state was also found to influence word processing in an explicit emotional categorization task which utilized the “oddball” paradigm (Imbir, Jarymowicz, Spustek, Kuś, & Żygierewicz, 2015). The task for participants was to ignore some standard stimuli and react to rare stimuli (emotional words) by deciding whether they were positive or negative. In this very early study, origin was demonstrated to influence amplitudes of evoked potentials in the P3/LPC component complex. In general, reflective originated stimuli evoked a more positive amplitude than automatic originated stimuli. Stimuli used in that study were not well balanced in concreteness; therefore, it is especially important to check the correlates of explicit word processing differing precisely in valence and origin. The current experiment is advancing the previous one not only with the more precise selection of stimuli, but also in the different version of emotion categorization task. The “oddball” paradigm (Imbir et al., 2015) enhances the P3 component, since the less frequent stimulus is a form of a surprise to the mind. In the current experiment, we had better opportunities to investigate the full spectrum of ERPs components indexing the word processing stages. Finally, the list of stimuli in the current experiment is based on emotion-laden words instead of emotion-label words included in an earlier investigation. Emotion-laden words rather than emotion-label-words were found to produce the more pronounced effects (Altarriba & Basnight-Brown, 2011).

### 1.4. Aim of the study and hypotheses

The current study aimed to investigate the neural correlates of decisions concerning the emotionality of stimuli. We were interested in testing the role of two dimensions of affective states, valence and origin, when other dimensions were controlled (arousal, concreteness, frequency of appearance and length). Considering behavioral results, we expected that both negative and positive words would be categorized as emotional more often than neutral words. Considering electrophysiological results, we expected both valence and origin to influence neural correlates of word processing. We had some predictions concerning results, derived from earlier studies investigating valence and origin effects on explicit emotional decisions (Imbir et al., 2015). We expected emotional effects on earlier (EPN) as well as later stages of processing (P3, N450, LPC). In general, we expected that both negatively and positively valenced words would evoke higher amplitudes of evoked potentials in comparison to neutral valenced stimuli. This effect is well recognized in the literature (Citron, 2012). The presence of expected valence effects would be a form of validation for the reliability of the procedure and support for the novel results associated with the origin factor. We also predicted that automatic originated words would elicit lower (in the sense of absolute value) amplitude evoked potentials than reflective originated stimuli. As stated in the emotion duality model (Jarymowicz & Imbir, 2015), valence and origin are distinct dimensions describing affective reactions, and therefore neural correlates attributed to valence and origin should be separated from one another. In other words, we expected to find main effects of these factors at distinct regions of interest (ROIs) or in distinct time windows (processing stages). Considering the stages of word processing and theoretical clues expressed before, we expected the valence to influence EPN (attention deployment) and P3 component (lexical access), while origin to influence N450 (the potential meaning inconsistencies) and LPC (post-semantic processing) components.

Due to the fact that investigation of effects associated with the origin of an affective state is pioneering, we decided on a two-step analysis. The first step was an exploratory and focused on time windows, while the second step was confirmatory and focused on ERP's components and their locations and time-ranges known from the literature (Citron, 2012; Luck & Kappenman, 2011).

## 2. Materials and methods

### 2.1. Participants

The participants were volunteers recruited from students of various Warsaw colleges and universities. They obtained a small reward for their participation in the experiment. Criteria for inclusion were: being right-handed, being a native Polish speaker, and having normal or corrected-to-normal vision. The whole examined group was 65 individuals (women = 31, men = 34) aged 19–25 years ( $M = 21.2$ ,  $SD = 1.6$ ). From this cohort, 9 participants were excluded from further analysis because they had more than 50% of trials rejected. The criteria for trial rejection were: EEG artifacts or extremely short or long response time, i.e., outside of the 90% confidence interval calculated from the distribution of response times of all 65 individuals. Effectively, the results presented below are based on the data of 56 individuals (women = 25, men = 31) aged 19–25 years ( $M = 21.3$ ,  $SD = 1.6$ ).

The bioethical committee approved the design, experimental conditions and consent procedure<sup>1</sup> for this study. All of the procedures involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

### 2.2. Design

We investigated the behavioral and electrophysiological correlates of the emotionality of written words. We manipulated the valence (Val) of the words (three levels: Neg—negative, Neu—neutral, and Pos—positive) and their emotional origins (Orig, three levels: Auto—automatic, Null—not specified, and Refl—reflective), while ensuring that stimuli were matched with respect to arousal, concreteness, frequency of appearance in language and length. Data on the number of correct and artifact-free trials were not normally distributed, so the effects relating to this variable were assessed using the Friedman test for replicated block designs. Other effects were assessed using ANOVA with repeated measures. Sphericity was checked with Mauchly's test, and the Greenhouse-Geisser correction was used where necessary. Post-hoc tests were performed using pairwise t-tests with the Holm (Holm, 1979) correction for multiple comparisons.

### 2.3. Linguistic materials

Linguistic materials consisted of nouns selected from an Affective Norms for Polish Words Reload (ANPW\_R (Imbir, 2016a)) dataset from among 4900 Polish words. The selection created a 3 (valence: Neg, Neu, Pos) x 3 (origin: Auto, Null, Refl) factorial manipulation with control for several potentially important factors, i.e., arousal, concreteness, frequency, and word length. Valence induced by the stimuli was measured with the use of a bipolar scale ranging from 1 (negative feelings) to 9 (positive ones). The origin scale was also bipolar and ranged from 1 (automatic origins) to 9 (reflective origins).

The assignment of words to levels was done according to their ratings compared to the distribution of ratings, namely: below  $-1$   $SD$ , from  $-0.5$  to  $0.5$   $SD$ , and above  $1$   $SD$  from the average rating in the corresponding dimension. In addition, the selected words had medium ratings (between  $-0.5$  and  $0.5$   $SD$ ) for arousal and for concreteness. We ensured also that the selected words were equalised in the frequency of appearance and length (Number of Letters: NoL). Frequency estimations were based on online internet Polish texts (Kazojć, 2011) and represented the number of occurrences of each word in the whole database used. The distribution of values in this database was right-skewed, which was corrected by natural logarithm LN transformation. Further parametric statistical analyses were conducted on the LN of frequency estimator. Ultimately, we selected 135 words (15 words in each of nine ( $3 \times 3$ ) categories (c.f. Appendix 1)). Table 1 presents mean values of manipulated as well as controlled factors for each of nine categories of words. Table 2 presents list of words in each category.

With the aim of testing adequateness of the selected words, several ANOVAs were carried out. We applied the 3 (valence levels) x 3 (origin levels) ANOVA analyses schema for each dimension measured. For manipulated variables the results were as follows. (1) **Valence ratings:** we obtained significant differences for the valence factor:  $F(2,126) = 607.44$ ,  $p < .001$ ,  $\eta^2 = 0.91$ , but not for the origin factor:  $F(2,126) = 1.88$ ,  $p = .16$ ,  $\eta^2 = 0.03$ , nor for the interaction between factors:  $F(4,126) = 2.09$ ,  $p = .086$ ,  $\eta^2 = 0.062$ . (2) **Origin ratings:** we obtained significant differences for the origin factor:  $F(2,126) = 254.55$ ,  $p < .001$ ,  $\eta^2 = 0.80$ , but not for the valence factor:  $F(2,126) = 1.27$ ,  $p = .28$ ,  $\eta^2 = 0.02$ , nor for the interaction between the factors:  $F(4,126) = 0.5$ ,  $p = .74$ ,  $\eta^2 = 0.016$ .

In the case of controlled variables, we obtained no statistically significant effects for the three dimensions. (3) **Arousal ratings:** no statistically significant effects were found (statistics summary: factor valence:  $F(2,126) = 1.98$ ,  $p = .14$ ,  $\eta^2 = 0.02$ , factor origin:  $F(2,126) = 1.44$ ,  $p = .24$ ,  $\eta^2 = 0.02$ , interaction between factors:  $F(4,126) = 0.5$ ,  $p = .72$ ,  $\eta^2 = 0.016$ ). (4) **Concreteness ratings:** no statistically significant effects were found (statistics summary: factor valence:  $F(2,126) = 1.19$ ,  $p = .31$ ,  $\eta^2 = 0.02$ , factor origin:  $F(2,126) = 0.4$ ,  $p = .67$ ,  $\eta^2 = 0.006$ , interaction between factors:  $F(4,126) = 0.12$ ,  $p = .98$ ,  $\eta^2 = 0.004$ ). (5) **Frequency of appearance**

<sup>1</sup> The participants provided informed consent to participate in the presence of at least two members of the research team and the fact was documented in a research diary. We did not collect any personal data (besides age and gender) that would allow identification of our participants.

**Table 1**

Word properties for each group of words calculated on the basis of ANPW (Imbir, 2015; 2016b).

Origin Category	Valence category	Negative		Neutral		Positive	
		<i>M</i>	( <i>SD</i> )	<i>M</i>	( <i>SD</i> )	<i>M</i>	( <i>SD</i> )
Automatic	Valence	3.50	(0.36)	5.02	(0.56)	6.71	(0.35)
	Origin	4.45	(0.53)	4.58	(0.37)	4.33	(0.70)
	arousal	4.37	(0.49)	4.15	(0.55)	4.28	(0.80)
	concreteness	4.31	(1.15)	3.95	(0.74)	4.48	(1.20)
	NoL	7.20	(2.65)	7.47	(1.96)	7.40	(2.41)
	Ln_freq	5.21	(1.91)	5.65	(2.03)	5.73	(2.28)
	Null	Valence	3.37	(0.36)	5.19	(0.54)	6.38
Origin		5.41	(0.31)	5.49	(0.30)	5.36	(0.35)
arousal		4.15	(0.23)	4.12	(0.67)	4.04	(0.51)
concreteness		4.05	(1.12)	3.96	(1.32)	4.17	(0.74)
NoL		6.47	(2.03)	5.27	(1.33)	6.93	(2.02)
Ln_freq		5.48	(2.28)	5.97	(1.27)	6.61	(2.02)
Reflective		Valence	3.66	(0.35)	5.30	(0.39)	6.49
	Origin	6.46	(0.30)	6.63	(0.41)	6.63	(0.56)
	arousal	4.32	(0.49)	3.93	(0.47)	4.03	(0.36)
	concreteness	4.17	(1.13)	4.09	(1.17)	4.41	(1.07)
	NoL	7.07	(1.75)	6.27	(1.62)	7.20	(2.27)
	Ln_freq	5.42	(1.37)	6.53	(1.79)	6.01	(1.22)

**of the words** in the Polish language: no statistically significant effects were found (statistics summary: factor valence:  $F(2,126) = 2.3, p = .11, \eta^2 = 0.04$ , factor origin:  $F(2,126) = 1.0, p = .37, \eta^2 = 0.016$ , interaction between factors:  $F(4,126) = 0.44, p = .78, \eta^2 = 0.014$ ). (6) **Average length of the words** revealed no significant effects either for valence factor ( $F(2,126) = 2.01, p = .14, \eta^2 = 0.03$ ) or for the interaction between valence and origin factors ( $F(4,126) = 0.82, p = .52, \eta^2 = 0.025$ ). But there was a simple effect of origin factor ( $F(2,126) = 3.48, p = .034, \eta^2 = 0.052$ ). The post-hoc analysis showed that the difference concerned words of Auto and Null origin levels:  $t(132) = 2.62, p = .01$ . Words of Auto origin were  $M = 7.3$  ( $SEM = 0.3$ ) letters long while words of Null origin were  $M = 6.2$  ( $SEM = 0.3$ ) letters long. The other differences were not significant.

The linguistic materials are the same as in our previous studies (e.g. Imbir et al., 2016); thus, more details concerning linguistic materials properties can be obtained there (c.f. Table 1, Imbir et al., 2016).

## 2.4. Procedure

### 2.4.1. Randomization

The stimulus material in this experiment consisted of 258 words: i.e. a set of 135 words selected for the manipulation of valence and origin (as described in Sect. 2.3), and a set of 123 additional words, which constitute material for another experiment and was equalised in terms of the Val and Orig properties at the moderate level, but differed in other dimensions of emotions (i.e. arousal and subjective significance levels). The list of all 258 words was permuted three times, for each subject separately. In this way, the order of the words on the list was randomised between the subjects and between the three repetitions of the list for a given subject. Data corresponding only to the 135 words with valence and origin manipulated will be analyzed in this manuscript. The possible effects of the other 123 words should be equally distributed across all combinations in the target manipulation and, therefore, do not interfere with the effects studied here. Nevertheless, such design resulted in a biased proportion of emotive to neutral words (90–168); therefore one may expect more positive amplitude of evoked potential at P3 stage for the rare category than for the more common category. A design involving random presentation of words differing in valence (negative, positive, and neutral) and origin (automatic, mixed, and reflective) combined with neutral words differing in activation properties (arousal and subjective significance) helped us to maintain theoretical coherence with assumptions expressed in Russell's (2003) model of core affect.

### 2.4.2. Experimental blocks

At the beginning of the experimental session, we instructed our participants (cf. procedure) that emotional words differ in two dimensions (valence and arousal), and then we asked them to assess the presented words as being emotional or not, considering both aspects of emotionality. The experiment session was divided into four blocks. Block 1 consisted of the presentation of 10 trials. Its aim was to adapt the subject to the experimental conditions. Data from this block were not analyzed. Stimuli from the above-described lists were sequentially presented in blocks 2, 3, and 4. After every 15 trials there was a 3 s break for blinking, to decrease eye-fatigue, and after each block there was a break with self-adjusted duration, which the subject could finish by pressing a continue key. All blocks of the experimental procedure were separated by closed-eyes and opened-eyes periods in order to separate subsequent repetitions of the main task by an unrelated task, to minimize the habituation effect.

### 2.4.3. The task and the timing of a single trial

Subjects were seated comfortably in front of a computer screen (at a distance of about 1 m) with one hand on the response

**Table 2**  
Words used in each condition.

		Valence Category					
		Negative		Neutral		Positive	
Origin Category	Automatic	<i>czkawka</i>	hiccup	<i>procesja</i>	procession	<i>zakochanie</i>	infatuation
		<i>szloch</i>	sob	<i>kościół</i>	church	<i>passa</i>	streak
		<i>łzy</i>	tears	<i>kuksaniec</i>	nudge	<i>toast</i>	toast
		<i>uszczyptnięcie</i>	pinch	<i>tarot</i>	tarot	<i>powitanie</i>	welcome
		<i>pijak</i>	drunk	<i>loteria</i>	lottery	<i>zapach</i>	fragrance
		<i>naïwniak</i>	sucker	<i>westchnienie</i>	sigh	<i>słodycz</i>	sweetness
		<i>stabeusz</i>	weakling	<i>jałmużna</i>	alms	<i>pomoc</i>	help
		<i>zmęczenie</i>	fatigue	<i>blazen</i>	clown	<i>niemowlak</i>	infant
		<i>hałas</i>	noise	<i>mrowienie</i>	tingling	<i>flirt</i>	flirt
		<i>plotka</i>	rumor	<i>pragnienie</i>	desire	<i>potomstwo</i>	offspring
		<i>grymas</i>	grimace	<i>obrzęd</i>	rite	<i>pozdrowienie</i>	greeting
		<i>gafa</i>	blunder	<i>wróżka</i>	fairly	<i>skarb</i>	treasure
		<i>usidlenie</i>	ensnaring	<i>młodzież</i>	youth	<i>walentyńka</i>	valentine
		<i>smarkacz</i>	stripling	<i>łasuch</i>	gourmand	<i>podarunek</i>	gift
		<i>zaślepienie</i>	infatuation	<i>burza</i>	storm	<i>ferie</i>	holiday
	Null	<i>wina</i>	fault	<i>doping</i>	cheering	<i>przyjęcie</i>	party
		<i>ciemnota</i>	unacquaintance	<i>chór</i>	choir	<i>rejs</i>	cruise
		<i>truchło</i>	carcass	<i>kłębek</i>	hank	<i>powiew</i>	waft
		<i>dół</i>	pit	<i>telewizja</i>	television	<i>promocja</i>	promotion
		<i>ochłap</i>	offal	<i>guru</i>	guru	<i>klimat</i>	climate
		<i>breja</i>	slush	<i>wódka</i>	vodka	<i>gość</i>	guest
		<i>paszkwil</i>	libel	<i>unik</i>	dodge	<i>brawa</i>	applause
		<i>kuternoga</i>	lame	<i>czara</i>	goblet	<i>kreskówka</i>	cartoon
		<i>reumatyzm</i>	rheumatism	<i>smok</i>	dragon	<i>melodia</i>	melody
		<i>biedak</i>	wretch	<i>blef</i>	bluff	<i>wydarzenie</i>	event
		<i>śpiączka</i>	coma	<i>żargon</i>	jargon	<i>smak</i>	taste
		<i>obtarcie</i>	sore	<i>głębia</i>	depth	<i>południe</i>	south
		<i>błąd</i>	error	<i>farsa</i>	farce	<i>malarstwo</i>	painting
		<i>łachmany</i>	rags	<i>grono</i>	bunch	<i>wyzwanie</i>	challenge
		<i>wada</i>	drawback	<i>pisarz</i>	writer	<i>obrońca</i>	defender
	Reflective	<i>egzamin</i>	exams	<i>szlachta</i>	nobility	<i>milliard</i>	billion
		<i>ignorancja</i>	ignorance	<i>etykieta</i>	label	<i>tolerancja</i>	tolerance
		<i>krata</i>	grating	<i>sultan</i>	sultan	<i>mistrz</i>	master
		<i>minus</i>	minus	<i>zadatki</i>	makings	<i>patent</i>	patent
		<i>szpieg</i>	spy	<i>prawo</i>	right	<i>dobytek</i>	property
		<i>koszty</i>	costs	<i>prasa</i>	press	<i>absolwent</i>	graduate
		<i>podwładny</i>	subordinate	<i>stawka</i>	bid	<i>uczony</i>	scholar
		<i>podatek</i>	tax	<i>raport</i>	report	<i>stypendium</i>	scholarship
		<i>alimenty</i>	alimony	<i>wojsko</i>	army	<i>szczyt</i>	peak
		<i>odsetki</i>	interest	<i>interes</i>	business	<i>równowaga</i>	balance
		<i>rząd</i>	government	<i>dyscyplina</i>	discipline	<i>oszczędności</i>	savings
		<i>przemyt</i>	smuggling	<i>wynik</i>	result	<i>płaca</i>	wages
		<i>recesja</i>	recession	<i>weto</i>	veto	<i>satyra</i>	satire
		<i>bezrobocie</i>	unemployment	<i>hodowla</i>	breeding	<i>lider</i>	leader
		<i>heretyk</i>	heretic	<i>kurs</i>	course	<i>zysk</i>	profit

keyboard. The subject's task was to read the word displayed on the screen and decide if it was emotional or neutral, then press a corresponding response key. The emotionality of words was defined for participants as having a certain intensity in the valence and arousal affective space (c.f. Fig. 2). The emotional words were defined as having a certain valence (positive or negative) and/or arousal level. The meaning of both dimensions was explained with intuitive examples (valence = pleasure vs. displeasure; arousal = excitement vs. sleep). Such a definition was presented in order to highlight the two-dimensional nature of emotionality associated with meaning of the words. Each trial consisted of the following sequence of screens: the fixation cross (for  $650 \pm 50$  ms.), the stimulus word (for as long as the subject took to decide and press a response key), a blank screen (for  $750 \pm 50$  ms.)

## 2.5. EEG materials

### 2.5.1. Apparatus

The stimuli were displayed on a standard personal computer monitor (LCD display; 15-inch diagonal). The stimuli and EEG data were synchronised using a custom-made hardware trigger.<sup>2</sup> EEG activity was recorded from 19 electrode sites: Fz, Cz, Pz, Fp1/2, F7/

<sup>2</sup> The trigger consisted of a circuit measuring the brightness of a small rectangular portion of the screen, which was covered by the trigger. The brightness of that part of the screen was changed at stimulus onset. The signal from the circuit was recorded, together with the EEG signal, on an

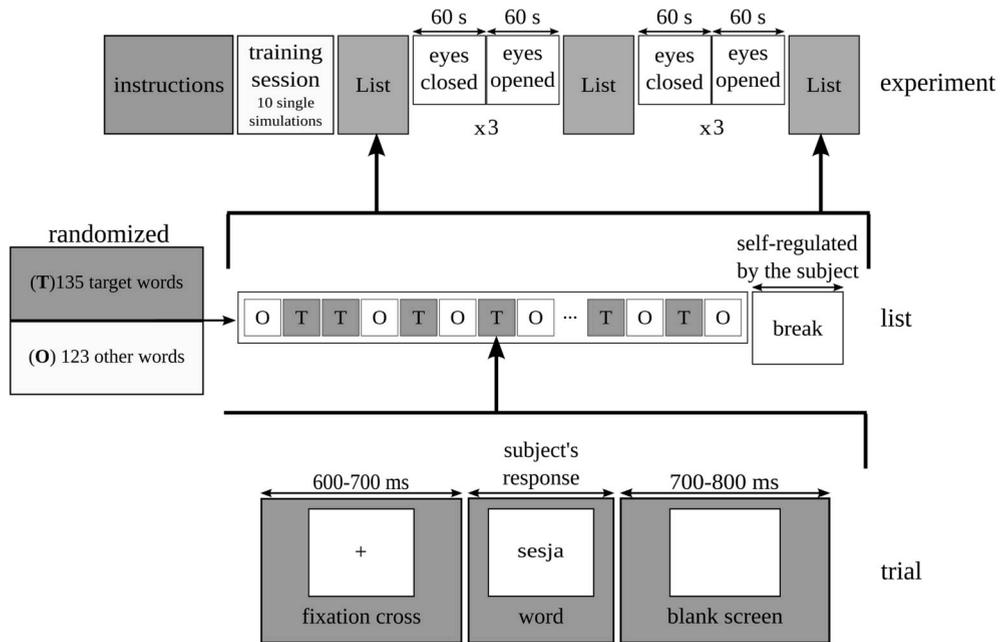


Fig. 2. Scheme of the procedure.

8, F3/4, T7/8, C3/4, P7/P8, P3/4, O1/2. The reference was linked earlobes. Ground electrode was placed at the AFz position. All impedances were kept at a similar value below 5 k $\Omega$ . The signal was acquired using a Porti7 (TMSI) amplifier, sampled at 1024 Hz.

### 2.5.2. Offline EEG signal processing

The offline processing of the signal was performed in Matlab<sup>®</sup> with the EEGLAB toolbox (Delorme & Makeig, 2004) and custom made scripts. The signal was zero-phase filtered. As a low-pass filter we used a second-order Butterworth with 12 dB/octave roll-off, with half amplitude cut-off frequency = 30 Hz. As a high-pass filter we used a first-order Butterworth with 6 dB/octave roll-off, and with half amplitude cut-off frequency = 0.01 Hz. Epochs from 200 ms before stimulus onset to 850 ms post-stimulus onset were extracted and baseline-corrected (baseline data taken from -200 ms to 0 ms). The dataset is available at <https://figshare.com/s/57ac6cc37fdc68a6250b> (<https://doi.org/10.6084/m9.figshare.8313815>).

### 2.5.3. Statistical analysis of ERP amplitude

The ERP effects were analyzed in a hierarchical fashion. On the first level we performed a three-way ANOVA (3 Val levels x 3 Orig levels x 4 ROI levels) with repeated measures for each of the time windows. The dependent variable was the ERP amplitude. It was averaged both across samples in a given time window and across the trials of a given combination of the factors. Holm correction (Holm, 1979) was used for tests of the same effect across the different time windows. The second level of analysis was conducted if for a given time window there was a significant effect of interaction between: Val and ROI, or Orig and ROI, or Val and Orig and ROI. It was further analyzed in that time window within each ROI separately by a two-way ANOVA (3 Val levels x 3 Orig levels) with repeated measures, applying Holm correction for the number of ROIs to each of the analyzed effects. Finally, if an effect for a given factor was significant at the second level, it was further tested with paired *t*-test to identify significant differences between levels of the factor. For this analysis we also used Holm correction. The procedure was implemented in the R statistical package (R Core Team, 2017).

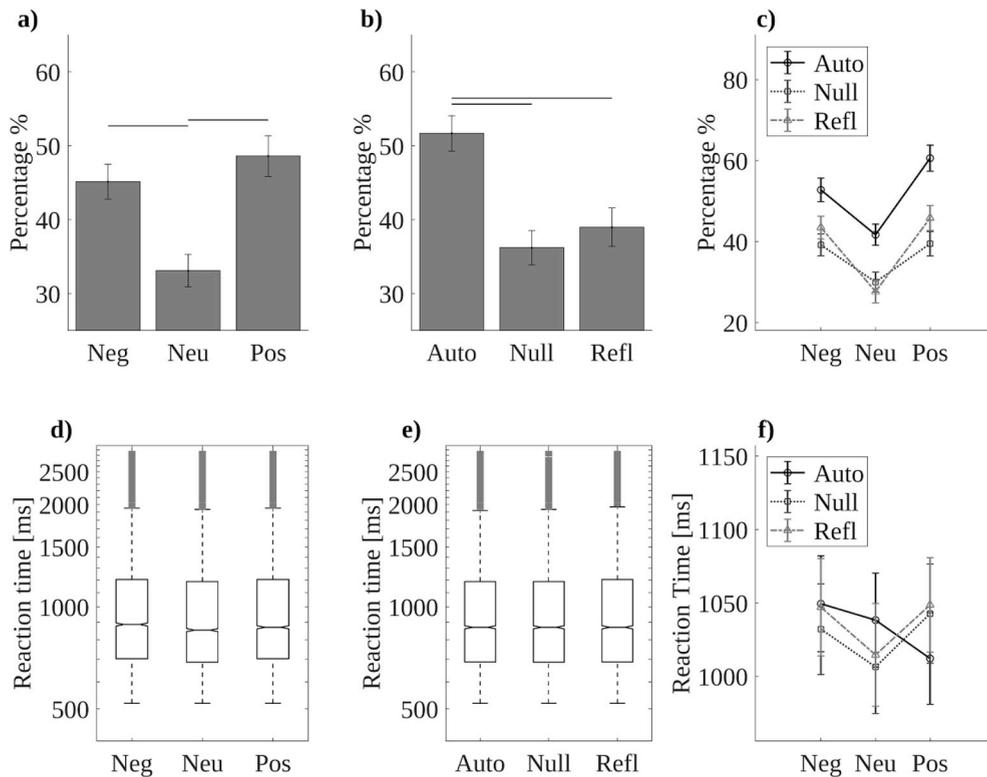
## 3. Results

### 3.1. Behavioral results

After exclusion of trials with response latency outside 90% of the total response latency distribution, the mean number of trials in each condition was  $M = 40.9$  ( $SEM = 0.2$ ). The Friedman test for replicated block designs indicated that the mean number of trials per condition was similar for the valence groups with origin as a blocking variable ( $\chi(2) = 0.108, p = .95$ ) and for the origin groups with valence as a blocking variable ( $\chi(2) = 2.257, p = .32$ ).

(footnote continued)

auxiliary input of the amplifier. This signal was later used to extract and align trial data.



**Fig. 3.** Behavioral results. Percentage of stimuli considered as “emotional” by participants: a) differences between valence levels, b) differences between origin levels, c) interactions between valence and origin of decision. Braces in a) and b) indicate significant differences. Reaction times in msec.: d) for the levels of valence, e) for the levels of origin, f) interactions between valence and origin reaction times. Error bars mark *SEM*.

### 3.1.1.1. Assessment of emotionality

We analyzed the percentage of words marked as containing emotional load. Assessment of emotion by the participants was strongly dependent on the level of Val, Orig, and the interaction between these factors. The results are shown in Fig. 3.

The main effect of Val ( $F(1.64, 90.67) = 28.445, p < .001$ ) was found statistically significant. Mauchly's test indicated that the assumption of sphericity had been violated for this factor ( $\chi^2(2) = 0.788, p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.82$ ). The percentage increased with the increase of emotional charge, both negative and positive, of a word; i.e., Neg ( $M = 45.14, SEM = 2.36$ ) was found to be significantly higher than Neu ( $M = 33.11, SEM = 2.21; t(55) = -6.85, p < .001$ ), and Pos ( $M = 48.62, SEM = 2.75; t(55) = 8.58, p < .001$ ) was found to be significantly higher than Neu as well. These relations are presented in Fig. 3 a. There was also significant effect of Orig ( $F(1.68, 92.67) = 30.112, p < .001$ ). Mauchly's test indicated that the assumption of sphericity had been violated for this factor ( $\chi^2(2) = 0.813, p < .003$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.84$ ). Here, the percentage differs in the case of Orig assessments; i.e., in Auto ( $M = 51.68, SEM = 2.39$ ), the percentage was significantly higher than in the Null condition ( $M = 36.21, SEM = 2.32; t(55) = -9.54, p < .001$ ), and it was also significantly higher than in the Refl ( $M = 38.98, SEM = 2.61; t(55) = -5.23, p < .001$ ) condition. These relations are presented in Fig. 3 b.

The interaction between Val and Orig factors was found to be statistically significant ( $F(4, 220) = 4.793, p < .001$ ). As can be seen in Fig. 3 c, an increase of emotional charge, i.e., positive and negative both had a statistically significantly higher percentage of words indicated as emotional than neutral for almost every simple difference. This pattern was significantly stronger for words of automatic origin than for reflective and null ones. The percentage in the Auto-Neg condition ( $M = 52.77, SEM = 2.99$ ) was significantly higher than the percentages in the other conditions, i.e., in the Auto-Neu condition ( $M = 41.69, SEM = 2.61; t(55) = -4.26, p < .001$ ), in the Null-Neg condition ( $M = 39.17, SEM = 2.71; t(55) = -6.05, p < .001$ ), in the Null-Neu condition ( $M = 29.99, SEM = 2.58; t(55) = -8.06, p < .001$ ), in the Null-Pos condition ( $M = 39.46, SEM = 3.02; t(55) = -4.27, p < .001$ ), in the Refl-Neg condition ( $M = 43.47, SEM = 2.82; t(55) = -3.18, p < .03$ ), and in the Refl-Neu condition ( $M = 27.64, SEM = 2.80; t(55) = -6.7, p < .001$ ). Also, the percentage in the Auto-Neu condition was significantly lower than in the Auto-Pos condition ( $M = 60.59, SEM = 3.26; t(55) = 6.5, p < .001$ ), and was significantly higher than the percentages in the Null-Neu condition ( $t(55) = -5.36, p < .001$ ) and the Refl-Neu condition ( $t(55) = -4.64, p < .001$ ). Furthermore, the percentage in the Auto-Pos condition was significantly higher than the percentages in the conditions listed below: the Null-Neg condition ( $t(55) = -5.47, p < .001$ ), the Null-Neu condition ( $t(55) = -8.49, p < .001$ ), the Null-Pos condition ( $t(55) = -10.01, p < .001$ ), the Refl-Neg condition ( $t(55) = -5.14, p < .001$ ), the Refl-Neu condition ( $t(55) = -9.68, p < .001$ ), and the Refl-Pos condition

( $M = 45.82$ ,  $SEM = 3.17$ ;  $t(55) = -5.27$ ,  $p < .001$ ). The percentage in the Null-Neg condition was significantly higher than percentages in the Null-Neu condition ( $t(55) = -4.31$ ,  $p < .001$ ), and the Refl-Neu condition ( $t(55) = -3.59$ ,  $p < .001$ ). Moreover the percentage in the Null-Neu condition was significantly lower than percentages in the following conditions: Null-Pos ( $t(55) = 3.70$ ,  $p < .001$ ), Refl-Neg ( $t(55) = 5.05$ ,  $p < .001$ ), and Refl-Pos ( $t(55) = 5.09$ ,  $p < .001$ ). The percentage in the Null-Pos condition was significantly higher than percentages in Refl-Neu condition ( $t(55) = -4.29$ ,  $p < .001$ ). The percentage in Refl-Neg condition was significantly higher than percentages in Refl-Neu condition ( $t(55) = -6.93$ ,  $p < .001$ ). Finally, the percentage in the Refl-Neu condition was significantly lower than percentages in Refl-Pos condition ( $t(55) = 8.38$ ,  $p < .001$ ).

### 3.1.2. Response latencies

Response latencies were measured as the interval between the onset of a word presentation and the press of a response key. Trials with extreme response latencies, i.e., those exceeding the top or the bottom 5 percent of the distribution (503 ms–2896 ms) obtained from all participants of the experiment, were eliminated from further analysis. The boxplots of values of reaction time (RT) are depicted in Fig. 3 d and e.

In order to transform the right-skewed distribution into an approximately normal one, and thus enable parametric statistics to be used, a natural logarithm transformation was applied to the subjects' reaction time data (Heathcote, Popiel, & Mewhort, 1991). Those natural logarithm-transformed response latencies were analyzed using a  $3 \times 3$  (Val x Orig) repeated measures ANOVA.

The response latencies differed between levels of valence ( $F(2, 110) = 4.86$ ,  $p < .001$ ) due to significant longer latency in the Neg ( $M = 1042$ ,  $SEM = 31$ ) than in the Neu ( $M = 1019$ ,  $SEM = 32$ ;  $t(55) = -3.65$ ,  $p < .002$ ) condition. The latencies differed also for the interaction between the factors of valence and origin. The interaction between Val and Orig factors ( $F(2, 110) = 4.73$ ,  $p < .001$ ) was statistically significant. Post-hoc analysis indicated that just two levels differed from each other. Namely, the response time in the Null-Neu condition ( $M = 1006$ ,  $SEM = 32$ ) was significantly faster than the response in the Refl-Neg condition ( $M = 1047$ ,  $SEM = 33$ ;  $t(55) = 3.41$ ,  $p < .04$ ) and the response time in the Refl-Neu condition ( $M = 1014$ ,  $SEM = 35$ ) was also significantly faster than the response in Refl-Neg condition ( $t(55) = -3.51$ ,  $p < .03$ ). These results are presented in Fig. 3 f.

## 3.2. Exploratory electrophysiological results

After exclusion of trials contaminated by artifacts (e.g. eye blinks or muscle activity), or with response latency outside the 90% of the total response latency distribution, the mean number of trials in each condition was 35.8 ( $SEM = 0.2$ ). This means that on average 9.2 trials were excluded from further analysis (about 22% of trials). The Friedman test for replicated block designs indicated that the mean number of trials per condition was similar for the valence groups with origin as a blocking variable ( $\chi(2) = 0.117$ ,  $p = .94$ ) and for the origin groups with valence as a blocking variable ( $\chi(2) = 1.866$ ,  $p = .39$ ).

### 3.2.1. Selection of time windows

ERP amplitude was analyzed in the time windows: 60–120 ms, 120–250 ms, 250–350 ms, 350–490 ms, and 490–690 ms. Selection of these ranges was based on the global field power curve (GFP). GFP corresponds to spatial standard deviation, at a given time point. It quantifies the sum of electrical activity over all electrodes (Lehmann & Skrandies, 1980; Skrandies, 1990). GFP maxima were used to determine the latencies of evoked potential components (Fig. 4). Microstates corresponding to the components are illustrated in the topographic plots of amplitude distribution at the bottom of Fig. 4.

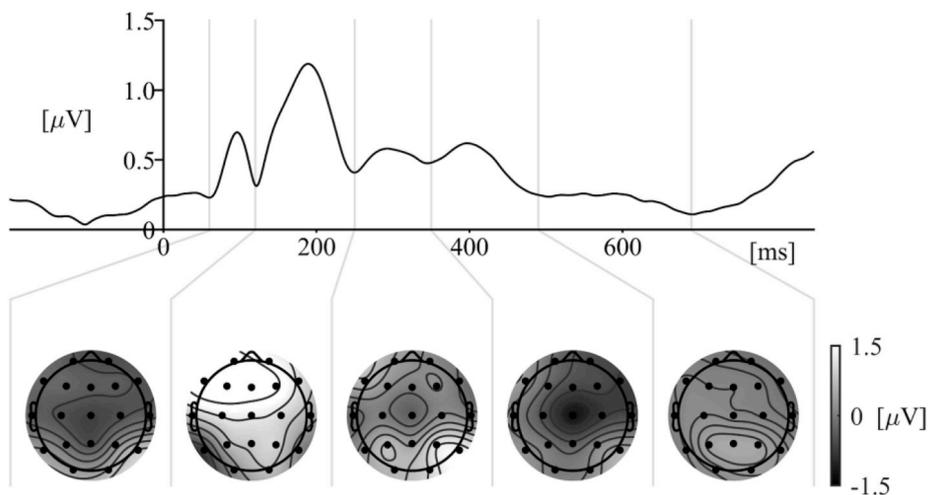
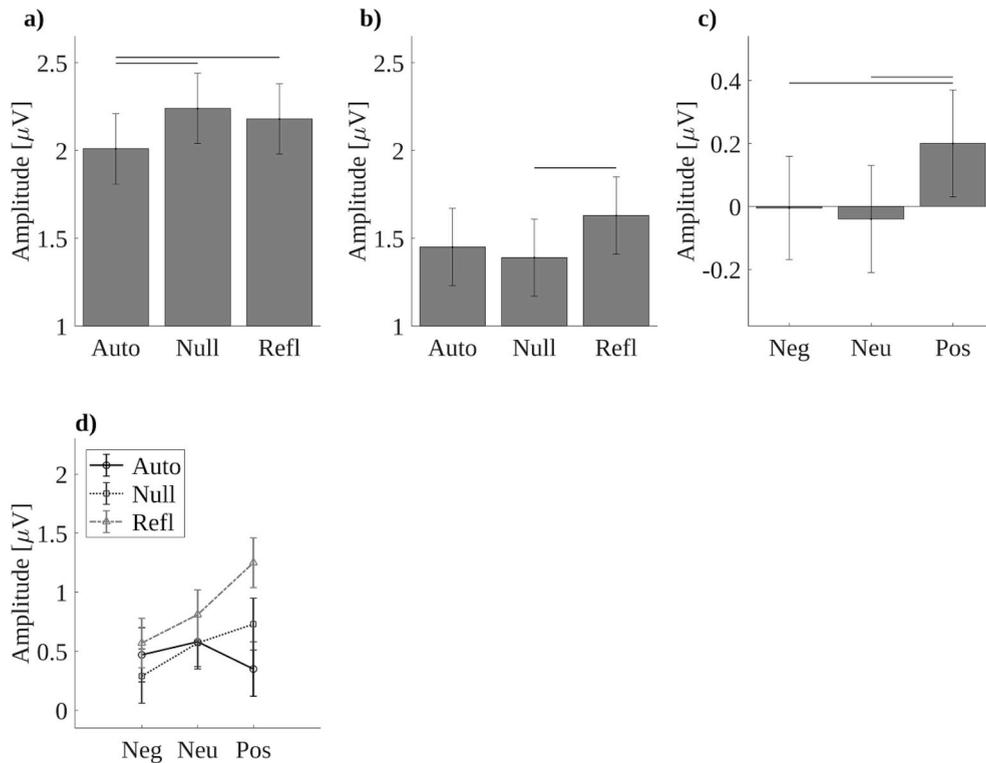


Fig. 4. Global field power (upper part) and topographies of average amplitude for a given time-window (bottom part). The vertical lines in the upper plot indicate time window boundaries.



**Fig. 5.** The effects on the first level of ERP analysis: a) main effect of Origin in the 120–250 ms time window, b) main effect of Origin in the 250–350 ms time window, c) main effect of Valence in the 350–490 ms time window. The braces on panels a), b), c) indicate the significant differences. Panel d) interaction of Val x Orig x ROI obtained on the second level of analysis in the RP ROI in the 350–490 ms time window. The error bars mark SEM.

### 3.2.2. Selection of regions of interest

We distinguished four regions of interest (ROI): left-frontal (LF: Fp1, F3, F7), right-frontal (RF: Fp2, F4, F8), left-parietal (LP: P3, P7, O1) and right-parietal (RP: P4, P8, O2). This selection of ROIs allowed us to examine the following contrasts: frontal vs. parietal and left vs. right, which plays an important role in the exploratory analysis.

### 3.2.3. Overview of the ERP results

The graphical overview complementing the detailed results of the statistical tests is presented in the following sections. The significant results obtained on the first level of analysis are illustrated in Fig. 5 a, b, and c.

The significant interactions of factors Val and Orig with ROIs obtained on the second level of analysis are represented by the gray backgrounds in Fig. 6 (Val x ROI) and Fig. 7 (Orig x ROI) together with the time-course of the ERP for each level of the factors: Val and Orig, respectively. The braces indicate significant differences between levels of the factor within a given ROI.

### 3.2.4. Time window 60–120 ms

No statistically significant effects were found in this time window.

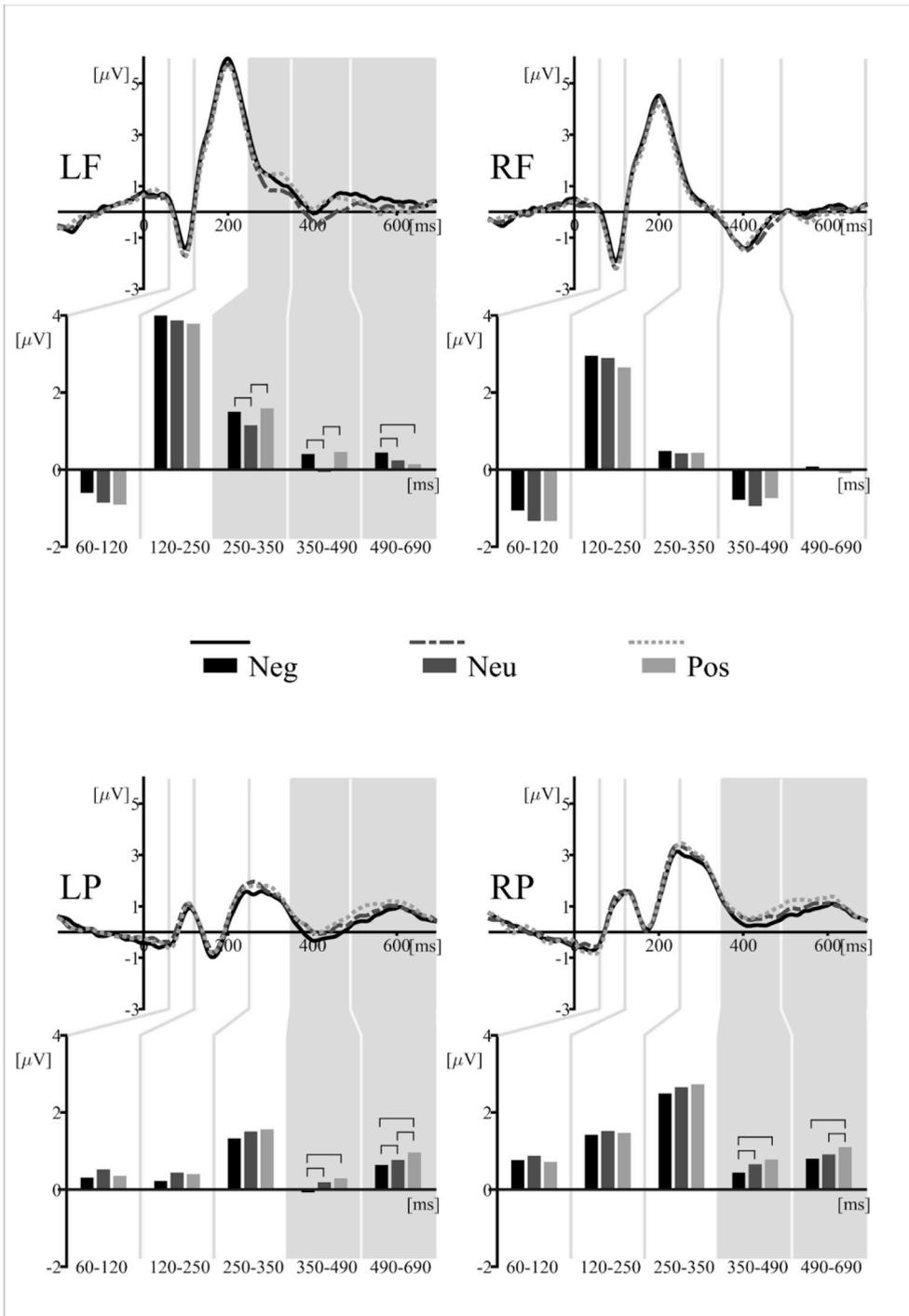
### 3.2.5. Time window 120–250 ms

The main effect of Orig ( $F(2, 110) = 5.352, p < .001$ ) was found statistically significant. The amplitude was less positive in the Auto condition ( $M = 2.01, SEM = 0.20$ ) than in Null ( $M = 2.24, SEM = 0.20; t(55) = 3.5, p < .003$ ) or Refl ( $M = 2.18, SEM = 0.20; t(55) = 2.32, p < .048$ ), as can be seen in Fig. 5 a.

### 3.2.6. Time window 250–350 ms

The main effect of Orig ( $F(2, 110) = 4.829, p < .001$ ) was statistically significant. The amplitude was less positive in the Null condition ( $M = 1.39, SEM = 0.22$ ) than in the Refl condition ( $M = 1.63, SEM = 0.22; t(55) = 3.0, p < .001$ ). Results are presented in Fig. 5 b.

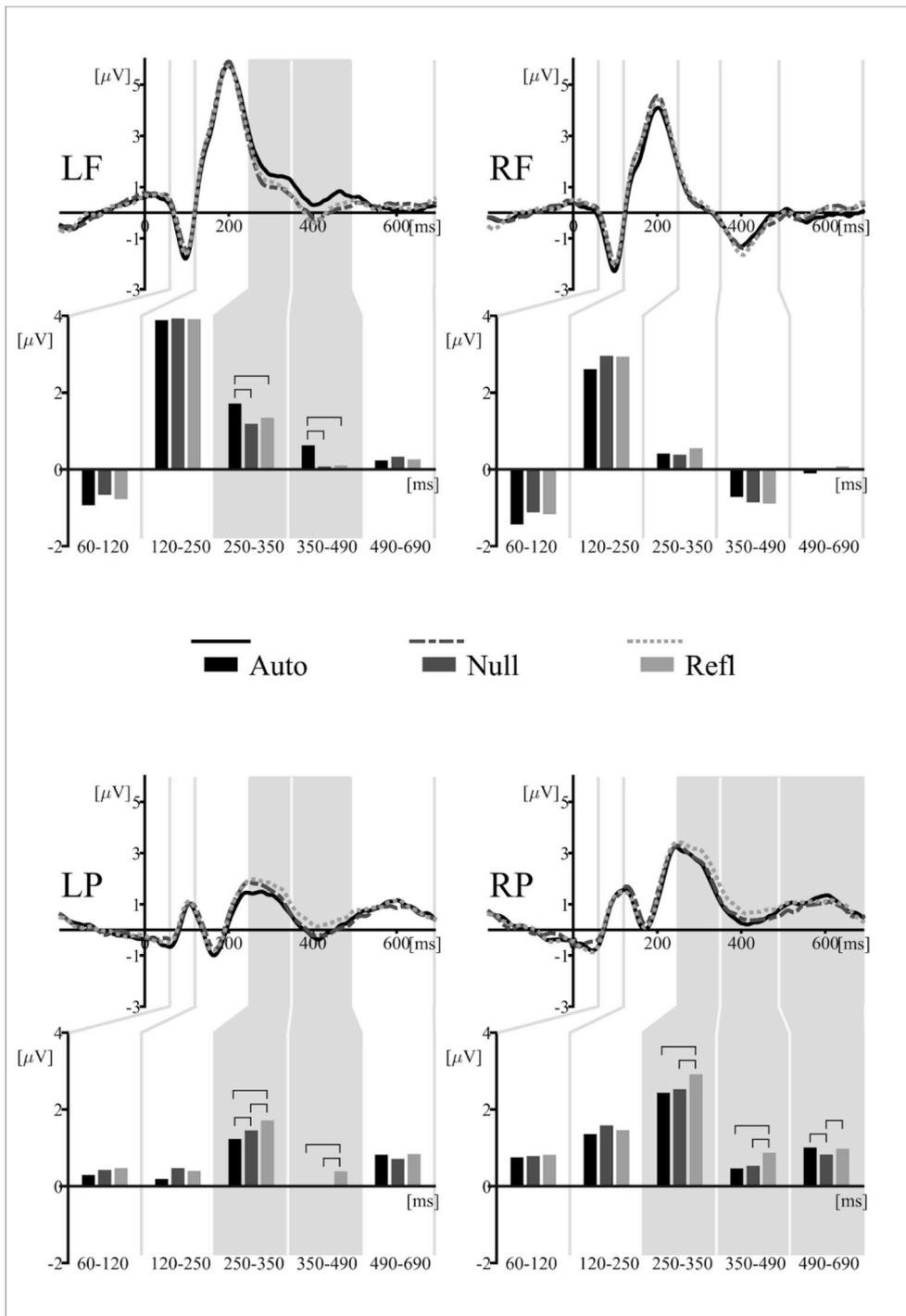
For the current time window, a statistically significant interaction between Val and ROIs ( $F(3.34, 184.0) = 4.714, p < .002$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.061, p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.56$ ). Further analyses within ROIs revealed a statistically significant main effect related to the levels of Val in LF ( $F(2, 110) = 6.122, p < .003$ ). Post-hoc tests showed that the



**Fig. 6.** Effects of Valence in subsequent time windows in different ROIs. For each ROI the time course of ERP for each level of Val is plotted. Gray backgrounds mark time windows with statistically significant effects. Beneath, the bars present the amplitude averaged within each time-window. Braces indicate significant differences.

amplitude in the Neg condition ( $M = 1.51$ ,  $SEM = 0.37$ ) was more positive than in the Neu condition ( $M = 1.15$ ,  $SEM = 0.38$ ;  $t(55) = -2.47$ ,  $p < .033$ ). They also showed that the amplitude in the Neu condition was significantly less positive than in the Pos condition ( $M = 1.59$ ,  $SEM = 0.37$ ;  $t(55) = 3.22$ ,  $p < .006$ ). These results are shown in Fig. 6.

For the current time window, a statistically significant interaction between Orig and ROIs ( $F(3.06, 168.78) = 10.526$ ,  $p < .001$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.026$ ,  $p < .001$ ); therefore,



**Fig. 7.** Effects of Origin in subsequent time windows in different ROIs. For each ROI the time course of ERP for each level of Orig is plotted. Gray backgrounds mark time windows with statistically significant effects. Beneath, the bars present the amplitude averaged within each time-window. Braces indicate significant differences.

degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.51$ ).

Further analyses within ROIs revealed a statistically significant main effect related to the levels of Orig in LF ( $F(2, 110) = 8.171$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Auto condition ( $M = 1.71$ ,  $SEM = 0.38$ ) was significantly more positive than in the Null condition ( $M = 1.19$ ,  $SEM = 0.37$ ;  $t(55) = -3.77$ ,  $p < .001$ ) or the Refl condition ( $M = 1.34$ ,  $SEM = 0.37$ ;  $t(55) = -2.65$ ,  $p < .021$ ). A statistically significant main effect related to the levels of Orig was also found in LP ( $F(2,$

110) = 12.075,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Auto condition ( $M = 1.23$ ,  $SEM = 0.26$ ) was significantly less positive than in the Null condition ( $M = 1.45$ ,  $SEM = 0.28$ ;  $t(55) = 2.6$ ,  $p < .02$ ) or the Refl condition ( $M = 1.17$ ,  $SEM = 0.26$ ;  $t(55) = -4.57$ ,  $p < .001$ ). They also showed that the amplitude in Null condition was significantly less positive than in the Refl condition ( $t(55) = 2.54$ ,  $p < .02$ ). The last statistically significant main effect related to the levels of Orig was found in **RP** ( $F(2, 110) = 13.487$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Auto condition ( $M = 2.44$ ,  $SEM = 0.28$ ) was significantly less positive than in the Refl condition ( $M = 2.92$ ,  $SEM = 0.26$ ;  $t(55) = 4.69$ ,  $p < .001$ ). They also showed that the amplitude in the Null condition ( $M = 2.53$ ,  $SEM = 0.29$ ) was significantly less positive than in the Refl condition ( $t(55) = 3.78$ ,  $p < .001$ ). All Orig results are presented in Fig. 7.

### 3.2.7. Time window 350–490 ms

The main effect of Val ( $F(2, 110) = 6.935$ ,  $p < .001$ ) was statistically significant. The amplitude was less positive in the Neg condition ( $M = -0.005$ ;  $SEM = 0.164$ ) than in the Pos condition ( $M = 0.24$ ,  $SEM = 0.17$ ;  $t(55) = 2.72$ ,  $p < .017$ ). Furthermore, the amplitude was less positive in the Neu condition ( $M = -0.04$ ,  $SEM = 0.17$ ) than in the Pos condition ( $t(55) = 3.67$ ,  $p < .002$ ). Results are shown in Fig. 5 c.

For the current time window, a statistically significant interaction between Val and ROIs ( $F(3.06, 168.58) = 8.024$ ,  $p < .001$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.039$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.51$ ).

Further analyses within ROIs revealed a statistically significant main effect related to the levels of Val in **LF** ( $F(2, 110) = 10.396$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Neu condition ( $M = -0.06$ ,  $SEM = 0.32$ ) was less positive than in the Neg condition ( $M = 0.41$ ,  $SEM = 0.30$ ;  $t(55) = 3.69$ ,  $p < .001$ ) or the Pos condition ( $M = 0.46$ ,  $SEM = 0.32$ ;  $t(55) = 4.04$ ,  $p < .001$ ). Furthermore, a statistically significant main effect related to the levels of Val was also found in **LP** ( $F(2, 110) = 10.819$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Neg condition ( $M = -0.08$ ,  $SEM = 0.18$ ) was less positive than in the Neu condition ( $M = 0.19$ ,  $SEM = 0.17$ ;  $t(55) = 4.11$ ,  $p < .001$ ) or the Pos condition ( $M = 0.29$ ,  $SEM = 0.17$ ;  $t(55) = 4.11$ ,  $p < .001$ ). The last statistically significant main effect related to the levels of Val was found in **RP** ( $F(2, 110) = 8.626$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Neg condition ( $M = 0.44$ ,  $SEM = 0.21$ ) was less positive than in the Neu condition ( $M = 0.65$ ,  $SEM = 0.20$ ;  $t(55) = 2.76$ ,  $p < .02$ ) or the Pos condition ( $M = 0.78$ ,  $SEM = 0.20$ ;  $t(55) = 3.99$ ,  $p < .001$ ). Results above are illustrated in Fig. 6.

For the current time window, a statistically significant interaction between Orig and ROIs ( $F(2.75, 151.65) = 14.64$ ,  $p < .001$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.028$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.46$ ).

Further analyses within ROIs revealed a statistically significant main effect related to the levels of Orig in **LF** ( $F(1.71, 94.05) = 13.016$ ,  $p < .001$ ). Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.83$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.85$ ). Post-hoc tests showed that the amplitude in the Auto condition ( $M = 0.63$ ,  $SEM = 0.33$ ) was significantly more positive than in the Null condition ( $M = 0.08$ ,  $SEM = 0.31$ ;  $t(55) = -4.55$ ,  $p < .001$ ) or the Refl condition ( $M = 0.10$ ,  $SEM = 0.30$ ;  $t(55) = -3.69$ ,  $p < .001$ ).

A statistically significant main effect related to the levels of Orig was also found in **LP** ( $F(2, 110) = 15.233$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Refl condition ( $M = 0.39$ ,  $SEM = 0.17$ ) was significantly more positive than in the Auto condition ( $M = 0.0$ ,  $SEM = 0.2$ ;  $t(55) = -4.85$ ,  $p < .001$ ) or the Null condition ( $M = 0.01$ ,  $SEM = 0.17$ ;  $t(55) = -4.21$ ,  $p < .001$ ).

The last statistically significant main effect related to the levels of Orig was found in **RP** ( $F(2, 110) = 13.092$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the Refl condition ( $M = 0.46$ ,  $SEM = 0.21$ ) was significantly more positive than in the Auto condition ( $M = 0.89$ ,  $SEM = 0.19$ ;  $t(55) = -4.69$ ,  $p < .001$ ) or the Null condition ( $M = 0.01$ ,  $SEM = 0.18$ ;  $t(55) = -4.21$ ,  $p < .001$ ). All Orig results are presented in Fig. 7.

The interaction between Val, Orig and ROI was statistically significant ( $F(6.23, 342.73) = 4.131$ ,  $p < .001$ ). Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(12) = 0.001$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.51$ ). Further analysis within ROIs revealed a statistically significant interaction between Val and Orig in **RP** ( $F(4, 220) = 5.465$ ,  $p < .001$ ) as can be seen in Fig. 5 d. Post-hoc analysis indicate that almost all levels differ from Refl-Pos. Namely, the amplitude in Refl-Pos ( $M = 1.25$ ,  $SEM = 0.21$ ) was significantly more positive than the amplitude in the other conditions: Auto-Neg ( $M = 0.47$ ,  $SEM = 0.23$ ;  $t(55) = -4.82$ ,  $p < .001$ ), Auto-Neu ( $M = 0.58$ ,  $SEM = 0.21$ ;  $t(55) = -5.36$ ,  $p < .001$ ), Auto-Pos ( $M = 0.35$ ,  $SEM = 0.23$ ;  $t(55) = -06.01$ ,  $p < .001$ ), Null-Neg ( $M = 0.29$ ,  $SEM = 0.23$ ;  $t(55) = -5.56$ ,  $p < .001$ ), Null-Neu ( $M = 0.57$ ,  $SEM = 0.22$ ;  $t(55) = -4.41$ ,  $p < .001$ ), Null-Pos ( $M = 0.73$ ,  $SEM = 0.22$ ;  $t(55) = -3.51$ ,  $p < .03$ ), and Refl-Neg ( $M = 0.57$ ,  $SEM = 0.21$ ;  $t(55) = -5.48$ ,  $p < .001$ ). Analysis also revealed that the amplitude in Null-Neg was significantly less positive than in Null-Pos ( $t(55) = 3.34$ ,  $p < .04$ ) or Refl-Neu ( $M = 0.81$ ,  $SEM = 0.21$ ;  $t(55) = 3.84$ ,  $p < .01$ ).

### 3.2.8. Time window 490–690 ms

For the current time window, a statistically significant interaction between Val and ROIs ( $F(3.08, 169.75) = 15.056$ ,  $p < .001$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.032$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.51$ ).

Further analyses within ROIs revealed a statistically significant main effect related to the levels of Val in **LF** ( $F(2, 110) = 6.122$ ,  $p < .003$ ). Post-hoc tests showed that the amplitude in the Neg condition ( $M = 0.44$ ,  $SEM = 0.13$ ) was more positive than in the Neu condition ( $M = 0.24$ ,  $SEM = 0.13$ ;  $t(55) = -2.78$ ,  $p < .01$ ) or the Pos condition ( $M = 0.14$ ,  $SEM = 0.14$ ;  $t(55) = -4.26$ ,

$p < .001$ ). Furthermore, a statistically significant main effect related to the levels of Val was also found in **LP** ( $F(2, 110) = 16.095$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the **Neg** condition ( $M = 0.64$ ,  $SEM = 0.10$ ) was less positive than in the **Neu** condition ( $M = 0.77$ ,  $SEM = 0.10$ ;  $t(55) = 2.43$ ,  $p < .02$ ) or the **Pos** condition ( $M = 0.96$ ,  $SEM = 0.09$ ;  $t(55) = 5.39$ ,  $p < .001$ ). Post-hoc tests also showed that the amplitude in the **Neu** condition was less positive than in the **Pos** condition ( $t(55) = 3.32$ ,  $p < .003$ ). The last statistically significant main effect related to the levels of Val was found in **RP** ( $F(2, 110) = 11.278$ ,  $p < .001$ ). Post-hoc tests showed that the amplitude in the **Pos** condition ( $M = 1.10$ ,  $SEM = 0.09$ ) was more positive than in the **Neg** condition ( $M = 0.8$ ,  $SEM = 0.10$ ;  $t(55) = -4.52$ ,  $p < .001$ ) or the **Neu** condition ( $M = 0.91$ ,  $SEM = 0.10$ ;  $t(55) = -2.91$ ,  $p < .001$ ). Results above are illustrated in Fig. 6.

For the current time window, a statistically significant interaction between **Orig** and **ROIs** ( $F(2.77, 152.38) = 4.05$ ,  $p < .01$ ) was observed. Mauchly's test indicated that the assumption of sphericity had been violated ( $\chi^2(6) = 0.016$ ,  $p < .001$ ); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.46$ ). Further analyses within **ROIs** revealed a statistically significant main effect related to the levels of **Orig** in **RP** ( $F(2, 110) = 4.665$ ,  $p < 0.011$ ). Post-hoc tests showed that the amplitude in the **Null** condition ( $M = 0.83$ ,  $SEM = 0.10$ ) was significantly less positive than in the **Auto** condition ( $M = 1.11$ ,  $SEM = 0.10$ ;  $t(55) = 2.72$ ,  $p < .03$ ) or the **Refl** condition ( $M = 0.98$ ,  $SEM = 0.10$ ;  $t(55) = 2.71$ ,  $p < .03$ ), as can be seen in Fig. 7.

### 3.3. Electrophysiological results for classical components

The same trials were analyzed with the more traditional approach, focusing on single ERPs components located in a specific **ROIs** at a certain time range (Luck & Kappenman, 2011). Such an approach allows us to validate an exploratory approach results as well as test directly hypotheses concerning stages of word processing.

#### 3.3.1. Selection of components time windows and ROIs

We decided to analyze four components found to be susceptible to words emotional properties, indexing subsequent stages of word processing, namely the **EPN**, the **P3**, the **N450** and the **LPC** component (Citron, 2012; Jończyk, 2016; Zhang et al., 2014). The selection of components locations and timing was based on the literature (Citron, 2012; Luck & Kappenman, 2011) and on the ERPs curves obtained in the current experiment, i.e., the timing of components was modified in order to fit best to the time course of ERPs fit best to the curves shapes and amplitude trends (c.f. Fig. 8 a, c, e, and g). The **EPN** was measured at P7, O1, O2, and P8 sites at 120–220 ms time range. The **P3** was evaluated at Cz and Pz sites at 250–350 ms time range. The **N450** component was measured at Fz and Cz sites at 300–500 ms time range. Finally, the **LPC** component was measured at P3, Pz, and P4 sites at 490–700 ms time range.

#### 3.3.2. The EPN component (120 ms–220 ms)

The main effect of **Orig** ( $F(2, 110) = 3.233$ ,  $p < .043$ ) was found statistically significant. The amplitude in the **Null** condition ( $M = 0.21$ ,  $SEM = 0.23$ ) was more positive than in the **Auto** condition ( $M = 0.02$ ,  $SEM = 0.24$ ;  $t(55) = 2.731$ ,  $p < .025$ ). The results are shown in Fig. 8 b.

#### 3.3.3. The P3 component (250 ms–350 ms)

The main effect of **Orig** ( $F(2, 110) = 11.456$ ,  $p < .001$ ) was found statistically significant. The amplitude was more positive in the **Refl** condition ( $M = 0.65$ ,  $SEM = 0.41$ ) than in the **Auto** condition ( $M = 0.03$ ,  $SEM = 0.43$ ;  $t(55) = 4.053$ ,  $p < .001$ ), and then in the **Null** condition ( $M = 0.13$ ,  $SEM = 0.44$ ;  $t(55) = 3.74$ ,  $p < .001$ ). The results are shown in Fig. 8 d.

#### 3.3.4. The N450 component (300 ms–500 ms)

The main effect of **Orig** ( $F(2, 110) = 3.361$ ,  $p < .038$ ) was found statistically significant. The amplitude was less negative in the **Refl** condition ( $M = -1.05$ ,  $SEM = 0.35$ ) than in the **Null** condition ( $M = -1.36$ ,  $SEM = 0.36$ ;  $t(55) = 2.617$ ,  $p < .034$ ). The results are shown in Fig. 8 f.

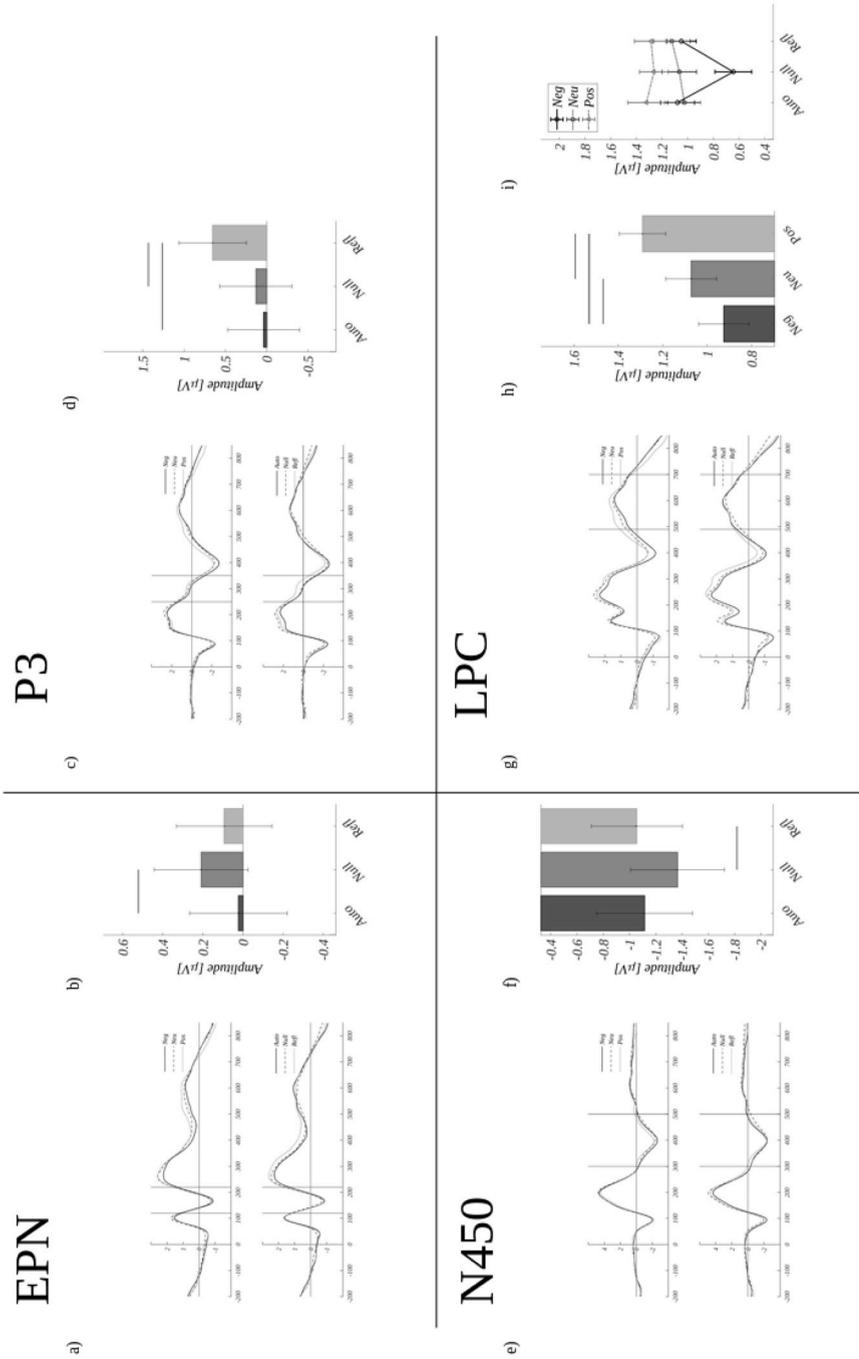
#### 3.3.5. The LPC component (490 ms–700 ms)

The main effect of **Val** ( $F(2, 110) = 13.833$ ,  $p < .001$ ) was found statistically significant. The amplitude was more positive in the **Pos** condition ( $M = 1.29$ ,  $SEM = 0.1$ ) than in the **Neg** condition ( $M = 0.93$ ,  $SEM = 0.11$ ;  $t(55) = 4.88$ ,  $p < .001$ ), and then in the **Neu** condition ( $M = 0.93$ ,  $SEM = 0.11$ ;  $t(55) = 3.537$ ,  $p < .002$ ). Also the amplitude was more positive in the **Neg** condition than in the **Neu** condition ( $t(55) = 2.028$ ,  $p < .047$ ). The results are shown in Fig. 8 h.

A statistically significant interaction between **Val** and **Orig** ( $F(4, 220) = 2.708$ ,  $p < .031$ ) was observed. Post-hoc tests showed that for **Neg** ( $F(2, 110) = 8.087$ ,  $p < .001$ ) the amplitude in the **Null** condition ( $M = 0.65$ ,  $SEM = 0.14$ ) was significantly less positive than in the **Auto** condition ( $M = 1.08$ ,  $SEM = 0.13$ ;  $t(55) = -3.561$ ,  $p < .002$ ), and was significantly less positive than in the **Refl** condition ( $M = 1.05$ ,  $SEM = 0.12$ ;  $t(55) = 3.689$ ,  $p < .002$ ). The interactions are shown in Fig. 8 i. Also, post-hoc tests showed that for **Null** ( $F(2, 110) = 13.644$ ,  $p < .001$ ) the amplitude in the **Neg** condition ( $M = 0.64$ ,  $SEM = 0.14$ ) was significantly less positive than in the **Neu** condition ( $M = 1.07$ ,  $SEM = 0.13$ ;  $t(55) = 3.722$ ,  $p < .001$ ), and was significantly less positive than in the **Pos** condition ( $M = 1.26$ ,  $SEM = 0.11$ ;  $t(55) = 4.69$ ,  $p < .001$ ).

## 4. Discussion

The aim of the current study was to investigate the role of valence and origin of an affective state in explicit word processing. Due



**Fig. 8.** The effects of classical ERP analysis: **EPN** in the 120–220 ms time window: a) the time course of mean signal from O1 and O2 electrodes for levels of Valence (top) and Origin (bottom); b) the main effect of Origin; **P3** in the 250–350 ms time window: c) the time course of mean signal from Pz and Cz electrodes for levels of Valence (top) and of Origin (bottom); d) the main effect of Origin; **N450** in the 300–500 ms time window: e) the time course of mean signal of Cz and Fz electrodes for levels of Valence (top) and of Origin (bottom subplot); f) main effect of Origin and of Valence in the 400–500 ms time window; **LPC** in the 490–700 ms time window: g) the time course of mean signal of P3, Pz, and P4 electrodes for levels of Valence (top) and of Origin (bottom h) main effect of Valence. Interaction of Val x Orig for: i) Valence and j) Origin. The braces on panels b), d), f), and h) indicate the significant differences. The error bars on panels b), d), f), h), and i) mark *SEM*.

to the fact, we have investigated a new concept of origin, the experiment was based mainly on an exploratory approach. Nevertheless, we had some expectations based on the literature (Citron, 2012), as well as on earlier studies focused on neural correlates of origin dimension (Imbir et al., 2016, 2015; Imbir, Spustek, Duda, et al., 2017b) and we have verified them in the light of classical component-based analysis of ERP. We predicted some behavioral differences in emotional words detection ratio. We also expected to find effects caused by origin dimensions on later, semantic and post-semantic stages of word processing (Citron, 2012; Zhang et al., 2014).

#### 4.1. Behavioral results

Behavioral results showed the expected effect of valence. Both positive and negative words were more often characterized as emotional than neutral words. Also, origin influenced the experience of the emotionality of words. Automatically originated stimuli were perceived as more emotional than null and reflective ones. This effect was present despite the fact that all origin groups of words were aligned in mean valence (c.f. word properties). Such an effect is not surprising, since automatic originated states have to be more accessible and more prototypical for emotional experiences (Jarymowicz, 2012; Jarymowicz & Imbir, 2015). The interaction of valence and origin found in the detection ratio further supports the validity of the previously stated conclusion, namely that the neutrally valenced word detection ratio was higher when they were of automatic origin than in other cases. This suggests that origin was treated on a subjective level as one of components of emotionality (especially automatic). Considering reaction latencies, it appeared that decisions concerning negative words took more time than decisions concerning neutral and positive stimuli. Also, an interaction of valence and origin was found. Inspecting raw means for all nine experimental conditions, it appears that the shortest reaction latencies were observed for the same conditions as higher and lower detection ratios, while the longest were observed for detection ratios oscillating around .4-.5. This means that decisions were quicker when they were obvious, and longer when there was some ambiguity in interpretation of a certain category. Such a relationship is consistent with the data collected with the use of the LDT paradigm, where the interaction between valence and arousal was found in reaction times (Bayer, Sommer, & Schacht, 2012). Negative-low-arousing words resulted there in longer reaction latencies in comparison to negative-high-arousing stimuli or positive- and neutral-low-arousing words. On the other hand, no reaction latency differences were reported in a similar study using an affective categorization task (Delaney-Busch et al., 2016) with lists of stimuli precisely contrasting valence and arousal. In the light of the current results this might be due to not accounting for the effects of origin.

#### 4.2. Valence effects in electrophysiological results

Considering exploratory electrophysiological results, there were clear patterns for the factors of valence and origin. It appeared that the main effect of valence was present at a relatively late stage of processing (350–490 ms). Amplitudes observed for positive words were more positive than amplitudes for neutral and negative stimuli. The valence effect interacted with specific ROIs: LF (250–690 ms), LP, and RP (both at 350–690 ms). The LF effect at the 250–350 ms and 350–490 ms time ranges closely resembles the pattern of behavioral differences in the case of detection ratio. The same pattern of correlations between reaction latencies and P2 component amplitudes was found in earlier studies focused on the emotional Stroop task paradigm at comparable time ranges (Imbir, Spustek, Bernatowicz, et al., 2017a). This suggests that decision processes may appear at a very early stage of processing. Posterior effects showed the increasing positivity of ERP's amplitudes from negative to positive words. The 490–690 ms time range may be interpreted in terms of the LPC component. The LPC component analysis confirmed the pattern of results for valence. The LPC component is thought to be a manifestation of post-semantic lexical processing (Bayer & Schacht, 2014; Citron, 2012; Jończyk, 2016; Kissler et al., 2009b) based on elaboration of associations of the given word meaning in memory. The LPC effect observed in the current experiment is consistent with data obtained in a reading paradigm (Herbert et al., 2006; Kissler et al., 2009a), but inconsistent with findings of studies utilizing a lexical decision paradigm (Citron et al., 2013) or emotional categorization (Delaney-Busch et al., 2016). The reasons for that may be twofold. First of all, the valence and origin are correlated one another in a curvilinear way (Imbir, 2016a), i.e. both negative and positive stimuli are perceived as evoking more automatic originated emotional experiences than reflective stimuli (the function describing this relation in ANPW\_R dataset is:  $origin = -.2valence^2 + 1.974 valence + 0.895$ ). From that reason the inclusion of the origin factor into the orthogonal manipulation with the valence may give us a chance to find the pure effect of valence. In the earlier experiments, valence groups of words may have differed in origins, thus the results may be different from one another, the same as in the case of concreteness found earlier (Kanske & Kotz, 2007). Second of all, the consistency of the current study results with the reading paradigms results may be due to the fact that response decisions were made earlier than the LPC time range.

The pattern of obtained EEG results in comparison to behavioral results suggests that decision-related processes occurred at LF ROI at 250–350 ms or at 350–490 ms. The pattern of amplitude differences at those location resembled closely the patterns of percentages for emotionality detection, both positive and negative groups differed from neutral group, but were different to reaction latencies pattern (where only negative stimuli evoked significantly longer response latencies). We can speculate that LF localization of decision-related correlates might be caused by to the verbalization of the emotional word stimuli in regions responsible for word production (Crosson et al., 1999). In order to give the answer in explicit emotional categorization, it was needed to read the stimulus word in mind (via silent reading requiring word production) and then decide whether the stimulus is emotional or not. Such verbalization should appear directly before the responding. The silent reading is a common process in all verbal paradigms (c.f. Chen et al., 2016; Kissler et al., 2009a). The time ranges suggest that the components responsible for those effects may be the P3 and the N450, but the classical component analyses for the P3 and the N450 components revealed no valence effects. This meant that LF ROI results reported cannot be attributed directly to the classical components.

To sum up, the processing at LPC component can be attributed to post-semantic lexical processing (Jończyk, 2016) that is involuntary (not forced by the instruction), rather than to discrimination of emotionality itself from neutrality (which occurred earlier in time, at 250–490 ms at LF region of interest). Our initial expectations to find the valence effects in earlier components of ERP in general are not supported by the classical component analysis. Each time the origin effects appeared instead.

#### 4.3. Origin effects in electrophysiological results

When it comes to the origin, the main effect was present at relatively early time ranges of 120–250 ms (amplitude for automatic originated stimuli was less positive than for other conditions) and 250–390 ms (amplitude for null stimuli was less positive than for reflective originated words). An early effect (120–250 ms) due to the amplitude distribution (peaks at posterior sites, but also at frontal regions: dipole pattern), should be interpreted in terms of EPN. The EPN component analysis revealed the main effect of origin that resembles partially the pattern of the global effect in an explorative approach. Namely, the amplitude for automatic originated stimuli was less positive than for null stimuli. In this component effects of valence were found in earlier studies (Citron et al., 2013), based on differences between emotional (negative and positive) and neutral words, but in the current experiment, no valence effects were found here. The EPN is thought to represent processes of lexical access, like identifying the visual stimulus as corresponding to a certain lexical representation in the mind (Citron, 2012). The later effect (250–390 ms) corresponds with the P3 component time range. The component-based analysis confirmed this interpretation. The pattern of results was congruent, the amplitude for null stimuli was less positive than for reflective originated words. Additionally, amplitude for automatic stimuli was also less positive than for reflective originated words. The P3 component is thought to index the lexical access stage of word processing (Citron, 2012; Jończyk, 2016; Kissler et al., 2006; Zhang et al., 2014). The reflective originated words, although matched in concreteness and frequency of appearance in language with other words groups, might be more semantically complex (De Deyne et al., 2017; Mitchell et al., 2008), therefore they evoke a more positive amplitude in this component.

When inspecting exploratory approach ROIs' specific differences, we may conclude that they appear at the same sites as differences caused by valence (LF, LP, and RP). Once more, the LF ROI pattern at 250–350 ms and 350–490 ms resembles behavioral differences in detection ratios; namely, amplitudes for automatic originated stimuli are significantly more positive than for all other conditions. Those differences cannot be attributed to classical components since EPN and P3 effects are distinct. The effects of origin at posterior ROIs start from 250 ms, which is earlier than the effects of valence, and stops at 490 ms for LP ROI, while at RP ROI it lasts longer, and also covers the time range specific to LPC component. The patterns of differences are distinct at 250–490 ms time ranges (frontal ROI shows more positive amplitudes for automatic originated stimuli in comparison in most of the cases to reflective originated stimuli, while parietal ROIs show reversed polarity) and at 490–690 ms time range (RP ROI show more positive amplitudes for automatic and reflective stimuli in comparison to null stimuli). The waveform suggests that the 350–490 ms time range may be interpreted as an N450 component. The component-based analysis revealed the origin effect in N450 that is partially congruent with LF ROI effect, i.e. reflective stimuli evoked less negative amplitude than null stimuli. This means that LF reflective stimuli effects can be attributed to the N450 component indexing a conflict detecting and monitoring (West, 2003; West & Alain, 2000). The waveform of the 490–690 ms time range suggests the interpretation in terms of an LPC component. The component-based analysis revealed no origin effect, but the significant interaction between valence and origin in the LPC component. The difference concerned the origin effect (more positive amplitudes for automatic and reflective stimuli in comparison to null stimuli) for only negative valenced stimuli. The LPC is a manifestation of post-semantic processing (Citron, 2012). The LPC effects are therefore partially similar to results observed at 490–690 ms RP ROI. This means that we may interpret origin effect in negative stimuli as caused by the classical LPC, while results collected at the 490–690 ms RP ROI showing the main effect of origin are probably due to the lateralized activation measured in RP ROI.

In earlier studies effects of origin were present at later time ranges (including LPC) (Imbir et al., 2016, 2015; Imbir, Spustek, Duda, et al., 2017b). For example, in the LDT (Imbir et al., 2016) paradigm at LPC time range in LF ROI we found the same pattern of differences present in the current experiment in RP ROI (more positive amplitudes for automatic and reflective words than for null conditions). The same differentiation due to origin of an affective state was present in an EST study (Imbir, Spustek, Duda, et al., 2017b) at a general level, but the pattern of differences was different, namely, automatically originated words evoked less positive amplitudes than reflective stimuli. The same pattern, as in the EST study, was present in LPC recorded during emotional decisions combined with the “oddball” paradigm (Imbir et al., 2015). This may be accounted for the context of cognitive control involved in EST and in inhibiting of responses in “oddball” probes of emotional categorizations. In the current study, and in the LDT study, participants had to react to all stimuli, therefore no control was needed.

#### 4.4. The current study limitations

Among limitations of the current experiment, we may notice that the chosen approach, based on stimuli selection, allows us to manipulate only two of the factors at a time forcing us to align the stimuli in respect to other factors. Specifically, there may be some interactions between valence and arousal or subjective significance (Imbir, Bernatowicz, Duda-Goławska, & Żygierewicz, 2018). Another limitation of the procedure utilized in the current experiment is associated with the fact, that valence-origin list was shown concurrently with arousal-subjective significance list of stimuli (another 123 words, cf. Fig. 2 and procedure section). This resulted in a biased number of neutral words. There was in fact, during the experiment, 45 neutral words from the current list and additional 123 neutral words from arousal-subjective significance list). Such disproportion could have influenced the P2/P3 amplitude, evoking more positive deflection for rare conditions in comparison to more common conditions (i.e. neutral). In order to check this, we

performed the analysis of the P3 component amplitude for the specific subjects and trials used in ERP analysis described in the current manuscript. Mean amplitude for electrodes Cz and Pz and for time interval 250–350 ms for stimulus identified as emotional ( $M = 0.02$ ,  $SEM = 0.32$ ) did not differ from the amplitude obtained for stimulus identified as not emotional ( $M = 0.26$ ,  $SEM = 0.29$ ;  $t(110) = 0.56$ ,  $p = 0.58$ ). It suggests that the number of emotional and neutral stimuli probably did not affect the results, as the difference in frequency of emotional vs. not-emotional stimuli was not enough to elicit differences in P3. Finally, behavioral results of the current experiment showed that at the conscious level reflective originated stimuli were not detected as emotional (were detected at a very similar level to null and neutral words). Nevertheless, EEG result showed that for example at LPC component time range conditions differing in origin evoked a precise differentiating pattern of amplitude. This may be due to the fact, that origin not always influences the behavioral level (Imbir, Spustek, Duda, et al., 2017b), but may shape only the underlying processing.

The origin factor is a relatively new proposition, therefore further studies are needed. First of all, it is interesting how origin interacts with arousal or subjective significance. To solve this question other lists of stimuli should be used, crossing in an orthogonal manner the origin and arousal or subjective significance. Another further direction in examining the origin of affective state consequences for word processing is to control for potential alternative explanations of results in terms of higher complexity of reflective originated stimuli in comparison to the automatic originated ones.

#### 4.5. Conclusions

In general, we observed that origin is more important than valence for understanding of emotional word processing correlates. The classical component analyses of the results suggest that origin shapes early and late stages of processing, while valence effects appear mostly in LPC component. This brings us to the conclusion, that the origin value is recognized (implicitly or explicitly) at the early stages of word processing and influence visual attention and semantic processing. The explorative approach in data analysis appeared to be more useful than classical component analysis, since it was shown to be more susceptible to both global and localized (or lateralized) differences caused by factors investigated. The current experiment therefore demonstrated that the origin of emotion is a significant factor that should be regarded in deliberation on emotional word processing. Omitting this factor might lead to inconclusive results. The current results indicate that origin of an affective state shapes both implicit and explicit word processing. We also demonstrated that origin effects are distinct from those of valence, both in exploratory analysis based on time ranges as well as classical component analysis. In addition to earlier studies (Imbir et al., 2015), the current experiment explicated that the effects of origin are independent of those of concreteness or arousal and that they are present even when concreteness levels are aligned across conditions. Surprisingly, effects of origin appeared in general to be earlier than valence effects. This means that origin in explicit emotional processing influences not only post-semantic stages of processing, but also shapes earlier stages, found by other researchers to be susceptible to differences in valence or arousal of words.

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#### Appendix A. Supplementary data

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