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MEANING RELATEDNESS IN POLYSEMOUS AND HOMONYMOUS WORDS: AN ERP STUDY IN RUSSIAN

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Previous research showed that polysemous and homonymous words are processed differently. However, mechanisms underlying processing of ambiguous words are still unclear. The goal of the present study was to investigate comprehension of metonymies, metaphors, and homonyms using priming paradigm and the method of event-related potentials (ERPs). We asked participants to read two-word phrases with ambiguous words and make a sensicality judgement. The results demonstrated the difference between metonymic and metaphorical senses of polysemous words in the amount of priming for the literal sense. The priming effect between metonymic and literal senses supports the idea that these senses share a single representation in the mental lexicon. In contrast, metaphorical senses of polysemous words showed a very limited priming effect on literal senses of the same words. Similar results were observed for different meanings of homonymous words. We conclude that metaphorical senses should have separate representations in the mental lexicon similarly to homonyms.

JEL Classification: Z.

Keywords: ambiguous words, metonymy, metaphor, homonymy, event-related potentials, the Russian language.

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Introduction

Theoretical studies on ambiguous words traditionally distinguish between homonymy and polysemy (Cruse, 1986; Lyons, 1977). In homonymy, a word accidentally carries two or more unrelated meanings, e.g. *bank 1* 'a financial institution' and *bank 2* 'an area of land along the side of a river'; while in polysemy, a word has several related senses, e.g. *funny rabbit* 'a small animal' and *tasty rabbit* 'the meat from a rabbit'. Within senses of polysemous words, two types of relations with the original literal sense can be distinguished: metonymy and metaphor (Apresjan, 1974; Geeraerts, 2010; Pustejovsky, 1995). Metonymy is motivated by contiguity: the shift from the original sense to a metonymic sense occurs within the same semantic domain, e.g. *funny rabbit →
tasty rabbit*, in this example the focus of attention shifts from the whole animal to its particular part – meat. Metonymic shifts are regular and predictable, they follow typical patterns (e.g. animal/food, capital/government, producer/product). Metaphor is motivated by analogy: one entity is presented in terms of another, e.g. *mouth of a child* 'the part of the face' and *mouth of the cave* 'the entrance to something'. Metaphorical shifts are not always obvious to speakers (Apresjan, 1974) and may have little in common with literal senses from which they were derived. Therefore, metaphors are considered as closer to homonyms while metonymies are far from them (see Apresjan (1974)).

Experimental psycholinguistic studies on homonymy are consistent with the theoretical assumption that different meanings of a homonymous word have separate representations in the mental lexicon and these representations compete for activation (Duffy, Morris, & Rayner, 1988). At the same time there is experimental evidence that homonymous and polysemous words are processed differently: homonyms had longer response latencies in lexical decision tasks (Klepousniotou, 2002; Klepousniotou & Baum, 2007) and they required longer fixation times in the reading task (Frazier & Rayner, 1990). Within polysemous words, metonymies and metaphors are also processed differently: metonymies were recognized faster than metaphors in lexical decision tasks (Klepousniotou, 2002; Klepousniotou & Baum, 2007) as well as in the sensicality judgement priming task (Klepousniotou, Titone, & Romero, 2008); literal senses were confused with metonymic senses more often than with metaphorical senses in the semantic clustering task (Lopukhina, Laurinavichyute, Lopukhin, & Dragoy, 2018). All this evidence leads to the conclusion that the degree of semantic closeness is related to the pattern of meaning storage in the mental lexicon: literal and metonymic senses of a polysemous word are stored in the same mental representations while literal and metaphorical – in separate representations (Klepousniotou & Baum, 2007; Klepousniotou et al., 2008).

In order to deeper investigate mechanisms underlying processing ambiguous words, experimental studies used electroencephalography (EEG) and magnetoencephalography (MEG), which both have very high temporal resolution. Pylkkanen, Llinás, and Murphy (2006) investigated the effect of priming between different senses of polysemous words with metonymic extensions and homonyms using MEG recording. They analyzed processing of ambiguous words within two-word phrases (targets) that were preceded either by a prime with the inconsistent meaning (e.g., *lined paper – liberal paper; river bank – savings bank*) or an unrelated prime (e.g., *military forces – liberal paper; salty dish – savings bank*). The authors focused on the latency of the M350 effect that reflected the priming effect between semantically related words (e.g. *liberal paper – daily magazine*) and was supposed to characterize processes of lexical activation. The results showed that the priming effect for polysemous words was reflected in the earlier M350 effect in the left hemisphere as compared to the condition with semantically related primes. According to the authors, the earlier latency of the M350 effect for targets preceded by the same polysemous word with inconsistent meaning indicates that different senses of polysemous words share one lexical entry. However, in some participants, polysemous targets also elicited a delay in the right-lateralized M350 effect, as compared to the semantically related targets. These results show that semantically related representations may interact in the right hemisphere differently depending on whether they belong to the same lexical entry (competition effect) or not (priming effect). Homonymous targets elicited an M350 delay in the left hemisphere as compared to the control condition. The authors suggested that different meanings of a homonym had separate lexical entries and inhibited each other when competing for activation.

While Pylkkanen and colleagues (2006) only focused on metonymies to investigate processing of polysemous words, the studies by Klepousniotou, Pike, Steinhauer, and Gracco (2012) and MacGregor, Bouwsema, and Klepousniotou (2015) also addressed processing of metaphors. The two studies focused on processing of polysemous words (both metonymies and metaphors) and homonyms (targets) that were used as a prime and were followed by targets either related to the dominant or subordinate meaning of the ambiguous word or unrelated. Both studies used the method of event-related potentials (ERPs) based on recording and analysis of EEG characterizing processing target words. Procedures of the experiments differed in the length of the interstimulus interval that was short (50 ms = 250 ms post-onset) in Klepousniotou et al. (2012) and long (750 ms = 950 ms post-onset) in MacGregor et al. (2015). After a short delay following the polysemous prime, target phrases that contained words related to both dominant and subordinate metonymic senses showed equally reduced N400 potential (a negative deflection that peaks about 400 ms post-stimulus that is associated with semantic processing) as compared to the unrelated

stimuli. In contrast, metaphors showed a significant difference between dominant- and subordinate-related targets, namely the priming effect on the target was more prominent for dominant senses mostly in the left hemisphere. In homonyms, priming effect was observed for both meanings and was more prominent for the targets following dominant meaning over the right hemisphere. Klepousniotou et al. (2012) indicate that although at the short interstimulus interval both meanings may be activated, there is a preference for the dominant meaning. The results of the study show the difference in the processing of homonymy and polysemy; they confirm that representation of metaphors differs from representation of both metonymies and homonyms and involves different neural mechanisms. This may be related to the fact that metaphors are more irregular in nature as compared to metonymy and depend more on context.

After a long delay (750 ms), N400 was reduced for targets related to both metonymic and metaphorical senses of polysemous words as compared to the unrelated condition (MacGregor et al., 2015). It indicates that after a long delay senses remain active, strengthen unified representation and facilitate processing of the target. There was also a reduction in P600 (a positive deflection that peaks about 600 ms post-stimulus and is associated with syntactic processing and reanalysis) for related targets that followed metonymies as compared to unrelated condition. For metaphors, a significant effect of late positivity was observed between subordinate- and dominant-related targets and both conditions did not differ from the unrelated targets. Whereas decay in the N400 amplitude may reflect increased activation of the subordinate meaning of metaphors after a long delay, increased positivity may be related to the competition process. In contrast to polysemous words, no N400 reduction for targets related to homonymous words was observed. This could be caused by a decay of both meanings related to lack of supportive context as well as competition between the meanings. In addition, there was a P600 effect for targets related to homonyms in the primes as compared to unrelated condition; this effects differed in amplitude between dominant and subordinate meanings. The difference was associated with difficulties in processing the target and relating it to the primes in homonyms in contrast to polysemous words in which the difficulty was reduced.

Meade and Coch (2017) used a short interstimulus interval (50 ms after prime offset, 250 ms after onset) in analysis of processing homonyms and reported a reduced N400 potential only for targets associated with dominant meanings of homonymous words as compared to unrelated primes. This shows that N400 amplitude is influenced by the meaning frequency in a minimal context. In addition, the amplitude of P600 potential was lower for targets related to dominant and subordinate meanings as compared to unrelated condition. These results contradict the results of MacGregor et

al. (2015) and, according to the authors, reflects the post-lexical reprocessing of the target and associating it with the prime.

Results of the previous studies show that processing ambiguous words may be modulated by the ambiguity type and meaning frequencies. However, mechanisms underlying processing of polysemous and homonymous words and the character of the difference between them is still unclear. The goal of the present study was to analyze processing metonymies, metaphors, and homonyms within two-word phrases using priming paradigm and method of ERPs. We experimented with polysemous words that have three senses (literal, metonymic, and metaphorical) in order to investigate how different non-literal senses (metonymic and metaphorical) interact with literal sense. For this purpose, we compared priming effects that phrases with literal or metonymic or metaphorical sense of the same word have on phrases with the literal sense. Similarly, we analyzed the priming effect between phrases with homonyms that have the same meaning or different meanings. Based on the previous studies, we expected that difference in processing metonymies, metaphors, and homonyms may be reflected in amplitude of both N400 and P600 potentials. We hypothesized that metonymies would provide a facilitation priming effect similar to the priming effect of same literal sense. Primes with metaphorical senses could have a facilitation effect on targets with literal senses, however this effect might be reduced as compared to metonymies, similarly to homonyms with different meanings.

Methods

Participants

Twenty four native speakers of Russian (16 females, mean age = 24.8, age range = 18-37) participated in the experiment. All participants were right-handed, had normal or corrected to normal vision, no history of neurological deseases, and signed an informed consent.

Materials

Experimental materials included 63 polysemous and 63 homonymous nouns. The polysemous nouns have literal, metonymic and metaphorical senses. Two-word (adjective- noun) phrases with literal sense (e.g. *nauchnyj zhurnal 'scientific journal'*) used as a target were preceded by prime phrases that have metonymic (*potrjopannyj zhurnal 'shabby journal'*) or metaphorical senses (*televizionnyj zhurnal 'television journal'*) of the noun. The ERP response to these conditions

was compared to the control condition in which targets were preceded by phrases with the same literal sense (*uvlekatelnyj zhurnal 'gripping journal'*). Similarly, phrases with homonyms (e.g., *lesnaja opushka 'forest edge'*) were preceded by phrases with the consistent (*zasnezhennaja opushka 'snow-covered edge'*) or inconsistent (*mehovaja opushka 'fur trimming'*) meaning. The experimental prime-target pairs were split into three experimental lists, so that each participant was presented with 21 trials in each condition and targets did not repeat within a list. One hundred sixty filler pairs of phrases were added to each list: 110 out of 320 phrases were sensible whereas 210 of them did not make sense. The order of trials was pseudorandomized within each experimental list with 8 participants assigned to each of the three lists.

Procedure

Word phrases within prime-target pairs were presented visually, in white on the black background. Each phrase started with a fixation cross (500 ms), followed by a adjective (700 ms) and a noun (until the button press). Participants were asked to judge whether the phrase made sense or not by pressing the left (for 'yes') or right (for 'no') arrow button on the keyboard. The experiment was preceded by a short practice session and lasted about 30 minutes with a short break in the middle.

EEG recording and analysis

The electroencephalogram (EEG) was recorded using 128 high-impedance ActiCap active electrodes (Brain Products Gmbh, Germany) mounted on an elastic cap and positioned according to the international 10-20 system. The EEG signal was recorded with 500 Hz sampling rate and referenced online to the linked mastoids. Impedances were kept below 10 kΩ. The EEG signal was band-pass filtered in 0.01-40 Hz frequency range. Continuous data were then segmented according to experimental conditions with 200 ms before and 1000 ms after the target noun onset. After correction for eye blinks (Fp1) using the Gratton and Coles algorithm (Gratton, Coles & Donchin, 1983), trials containing artifacts were automatically excluded from the analysis. The baseline correction was performed relative to ‑200-0 ms prestimulus interval and average ERPs were calculated according to the experimental conditions.

Statistics

The effect of priming was examined in the standard time windows for the N400 and P600 effect – 300-500 ms and 500-800 ms, correspondingly. For the statistical analysis, the midline electrodes were divided into three groups: frontal (AFz, Fz), central (FCz, Cz, CPz), and posterior

(Pz, POz, Oz). Twelve groups of lateral electrodes were created (frontal: left (AFp1, AF3, AF7), right (AFp2, AF4, AF8); fronto-central: left (AFF1h, AFF5h, F1, F3, F5, FFC1h, FFC3h, FFC5h), right (AFF2h, AFF6h, F2, F4, F6, FFC2h, FFC4h, FFC6h); central: left (FC1, FC3, FC5, FCC1h, FCC3h, FCC5h, C1, C3, C5), right (FC2, FC4, FC6, FCC2h, FCC4h, FCC6h, C2, C4, C6); centro-parietal: left (CCP1h, CCP3h, CCP5h, CP1, CP3, CP5, CPP1h, CPP3h, CPP5h), right (CCP2h, CCP4h, CCP6h, CP2, CP4, CP6, CPP2h, CPP4h, CPP6); parietal: left (P1, P3, P5, PPO1h, PPO5h), right (P2, P4, P6, PPO2h, PPO6h), occipital: left (PO3, PO7, POO1, O1), right (PO4, PO8, POO2, O2)). The group values were calculated as an average of the electrodes included.

ERP effects were analyzed using repeated measures ANOVAs separately for polysemous and homonymous words with *Condition* (metonymic vs. literal sense prime, metaphorical vs. literal sense prime for polysemous words; inconsistent vs. consistent prime for homonyms), *Posteriority* (midline groups: frontal, central, posterior; lateral groups: frontal, fronto-central, central, centro-parietal, parietal, occipital) and *Hemisphere* (for lateral groups only: left, right) as within-subject factors. When the assumption of sphericity was violated, the Greenhouse-Geisser correction was applied.

Results

Behavioral results

Response accuracy and reaction times for targets in different experimental conditions are presented in Table 1.

Statistical analysis of accuracy showed a marginally significant difference among experimental conditions with polysemous targets (Friedman test: $\chi^2 = 4.6$, $p = 0.099$). Pairwise comparisons did not revealed significant results (ps > 0.1). In contrast, difference between homonymous targets with consistent and inconsistent primes was statistically significant (Wilcoxon test: $W = 16$, $p = 0.001$): participants did more errors for homonymous targets preceded by inconsistent primes as compared to the control condition.

Analysis of reaction times did not show significant difference among experimental conditions with polysemous or homonymous targets.

Table 1. Response accuracy and reaction times per condition

Ambiguity Type	Prime	Accuracy (%): Mean (SD)	Reaction Times (ms): Mean (SD)
Polysemous word			
	Literal	93.8 (7.1)	899 (368)
	Metonymic	91.7 (8.9)	958 (403)
	Metaphorical	91.7 (9.5)	925 (284)
Homonymous word			
	Consistent	85.7 (10)	933 (302)
	Inconsistent	76.6 (12.6)	978 (272)

ERP results

In the *300-500 ms* time window, analysis of processing polysemous words did not show effect of *Condition* or its interaction with other factors for the metonymic and control conditions in the midline electrode groups (see Figure 1). A tendency for *Condition* by *Hemisphere* interaction ($F(1,23) = 3.64$, $p = 0.069$) was observed in the lateral electrode groups. However, post-hoc analysis did not show significant effect of *Condition* in either hemisphere.
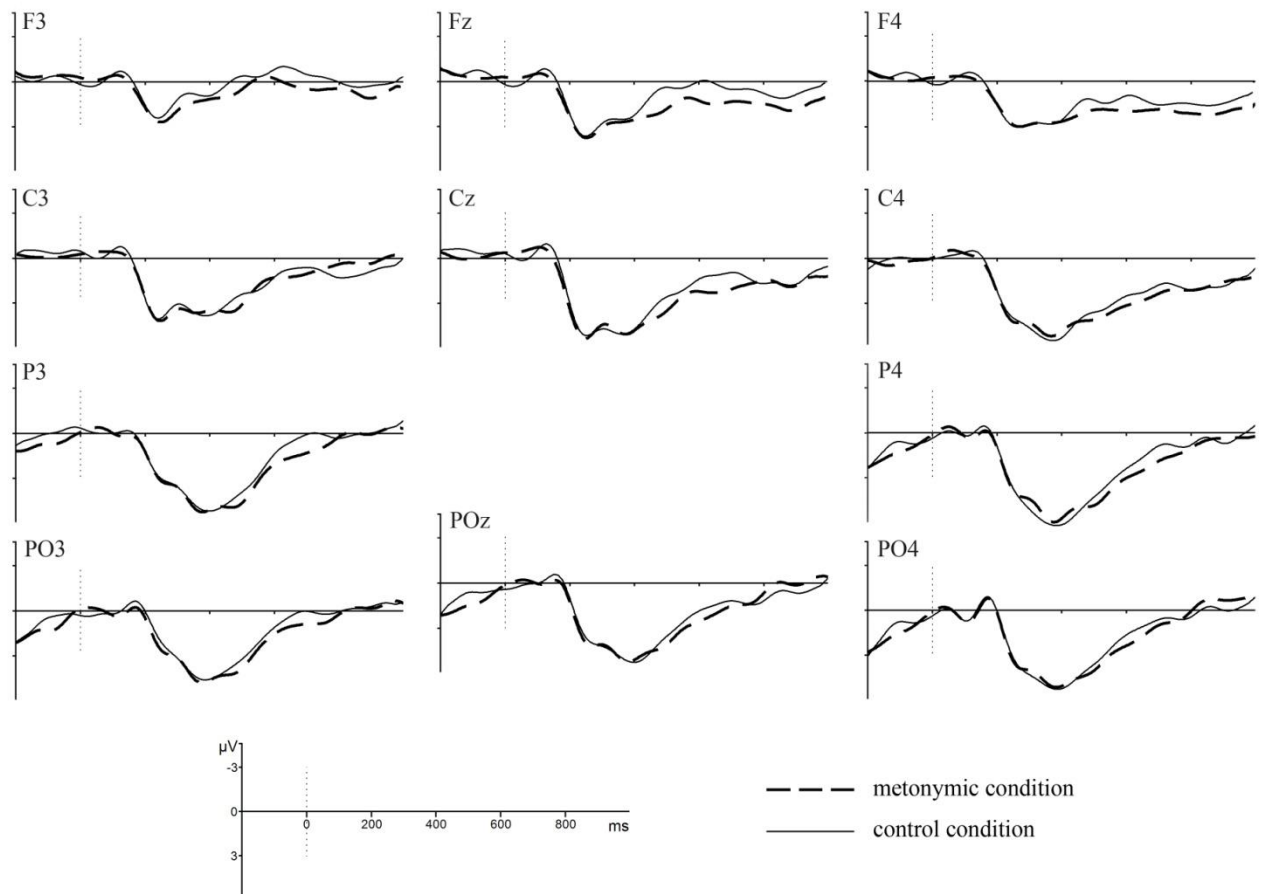
Figure 1. Grand average ERPs for polysemous words preceded by primes with metonymic (metonymic condition) and literal (control condition) meanings. Negative is plotted up.

Statistical analysis of difference between the metaphorical and control conditions (Figure 2) revealed a marginally significant *Condition* by *Posteriority* ($F(2,46) = 2.44$, $p = 0.098$) interaction in the midline electrode groups. Post-hoc analysis showed that the amplitude of the N400 potential was higher for phrases with literal sense that were preceded by metaphorical phrases as compared to the control condition in the central electrode group ($F(1,23) = 5.40$, $p = 0.029$). Statistical analysis in the lateral electrode groups did not show effect of *Condition* or its interaction with other factors.

Analysis of ERPs accompanying processing homonymous targets did not show significant difference between the two experimental conditions in the midline or lateral electrode groups.

In the *500-800 ms* time window, statistical analysis did not show significant difference between the metonymic and control conditions in the midline or lateral electrode groups.
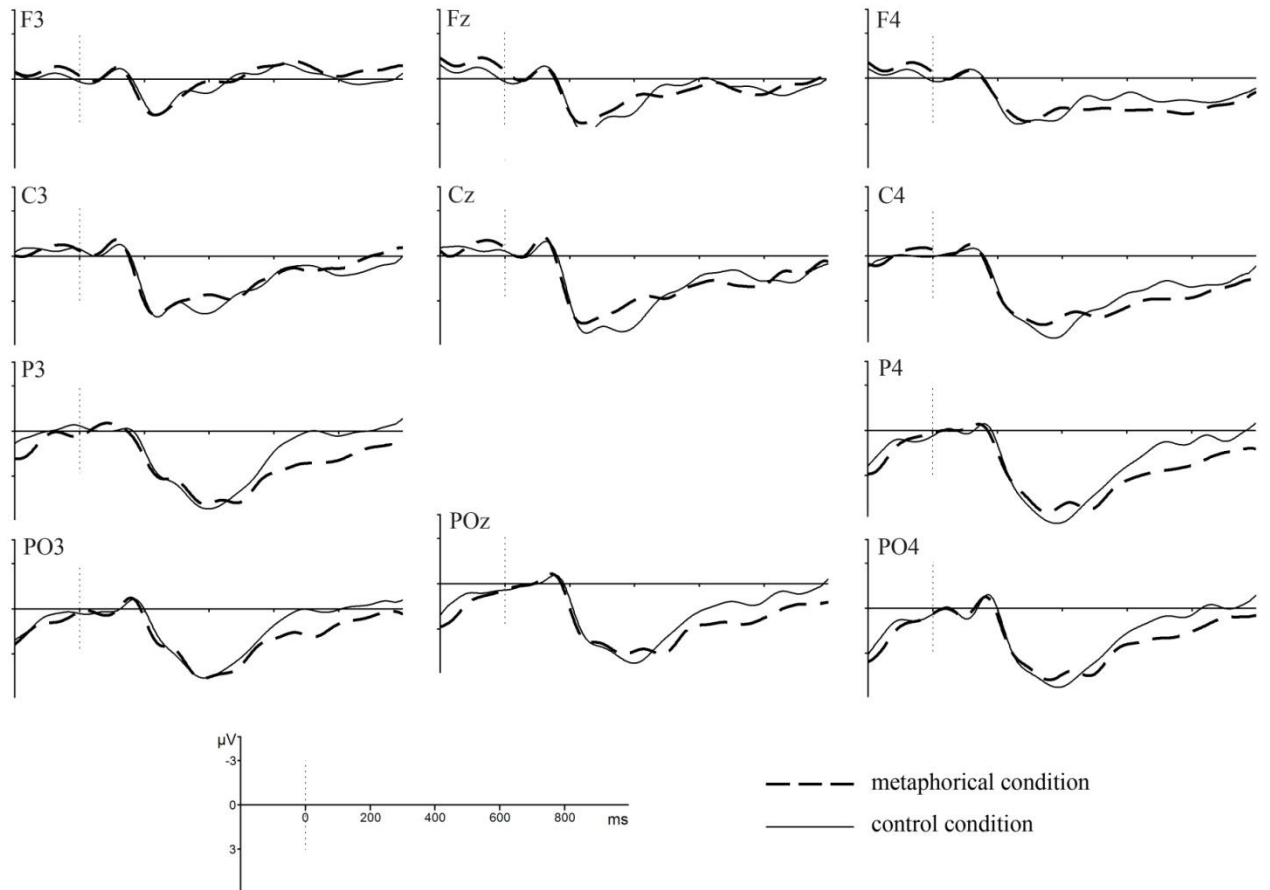
Figure 2. Grand average ERPs for polysemous words preceded by primes with metaphorical (metaphorical condition) and literal (control condition) meanings. Negative is plotted up.

Concerning comparison of metaphorical and control conditions, a significant *Condition* by *Posteriority* ($F(2,46) = 5.06$, $p = 0.01$) interaction was observed in the midline electrode groups. According to the post-hoc analysis, the P600 effect that characterized processing polysemous targets preceded by metaphorical phrases as compared to the control condition was marginally significant in the posterior group ($F(1,23) = 3.35$, $p = 0.08$). In the lateral electrode groups, there was a marginally significant *Condition* by *Posteriority* ($F(5,115) = 2.76$, $p = 0.075$) interaction. Post-hoc analysis showed a tendency for a P600 effect in the occipital ($F(1,23) = 3.35$, $p = 0.08$) electrode groups.

Difference between the inconsistent and consistent conditions for homonymous targets was reflected in the marginally significant effect of *Condition* ($F(1,23) = 3.83$, $p = 0.063$) in the midline electrode groups (Figure 3). In the lateral electrode groups, a significant *Condition* by *Posteriority* ($F(5,115) = 4.62$, $p = 0.012$) interaction was observed. Post-hoc analysis showed that a significant

P600 effect accompanies processing homonymous targets in the inconsistent as compared to the consistent condition in the centro-parietal ($F(1,23) = 4.96$, $p = 0.036$) and parietal ($F(1,23) = 10.85$, $p = 0.003$) electrode groups.
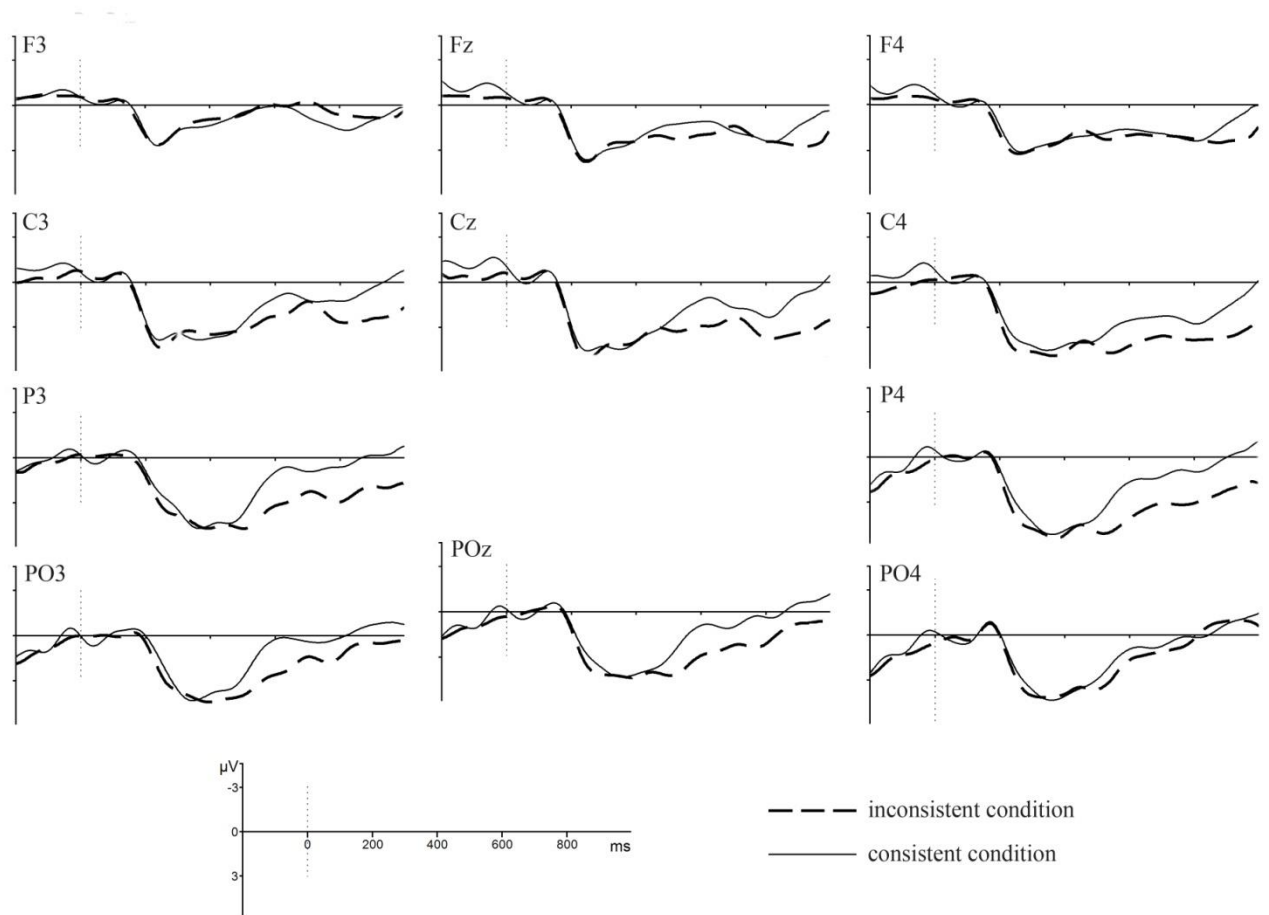

Figure 3. Grand average ERPs for homonymous words preceded by primes with inconsistent (inconsistent condition) and consistent (consistent condition) meanings. Negative is plotted up.

Discussion

The present study investigated processing polysemous and homonymous Russian words. We analyzed event-related potentials (ERPs) accompanying reading ambiguous nouns in two-word phrases. Our materials included polysemous words with literal, metonymic, and metaphorical senses as well as homonymous words with two meanings. The comparison of different senses within a single word allowed us to analyze their interaction. We used a priming paradigm and asked participant to read phrases word by word and make a sensicality judgement. We focused on the

amplitude of N400 and P600 potentials and hypothesized that phrases with metonymic senses would provide a priming effect on phases with literal senses. We expected that the effect would be comparable to the priming effect of the same sense. In contrast, we supposed that phrases with metaphorical sense would provide a limited priming effect on polysemous words with literal sense, similarly to homonymous primes that do not coincide in the meaning with the target.

Our behavioral results did not show significant difference for accuracy rates and reaction times among polysemous words with different senses. It means that our behavioral measures are unable to distinguish between the processing of polysemous words with literal, metonymic, and metaphorical senses. However, electrophysiological data demonstrated the difference between metonymic and metaphorical senses in the amount of priming for the literal sense. ERP analysis did not reveal significant difference in N400 or P600 amplitude between target phrases with literal senses preceded by primes with the same literal and metonymic senses. These results indicate that priming effect on phrases with literal senses was comparable for phrases with metonymic and with literal senses. Our results are in line with the results of previous studies (Klepousniotou et al., 2012; MacGregor et al., 2015; Pylkkanen et al., 2006). The observed priming effect between metonymic and literal senses of polysemous words supports the idea that these senses share a single representation in the mental lexicon which is reflected in spreading activation between them.

In contrast to metonymic primes, a local N400 effect as well as a marginally significant P600 effect were observed for target words with literal senses preceded by phrases with metaphorical senses as compared to the control condition. The observed effects show that metaphorical senses of polysemous words have a very limited priming effect on literal senses of the same words. The N400 effect may reflect processes of lexical access to the target sense of the word whereas the P600 effect might be a marker of competition between the two word senses and of the relative difficulties that participants had with sensicality judgements that followed words processing. The observed results show that metaphorical senses are farther from literal senses of polysemous words as compared to metonymic senses and may be stored in different representations. This is in line with the results of the previous behavioral (Klepousniotou & Baum, 2007; Klepousniotou et al., 2008) and ERP (Klepousniotou et al., 2012; MacGregor et al., 2015) studies.

In homonymous words, behavioral data show that participants made more sensicality judgement errors for target phrases preceded by homonymous prime with the inconsistent meaning as compared to the consistent control condition. The ERP data show that difference between the two experimental conditions is also reflected in the electrophysiological response: a significant increase in the P600 amplitude was observed for phrases with homonymous words preceded by the prime

with the other meaning. These results may indicate processing difficulties related to switching between meanings of homonymous words together with a competition and task effects. Modulation of the P600 effect related to meanings of homonymous words was also presented in the studies of MacGregor et al. (2015) and Meade and Coch (2017), but in these studies the effect goes in the opposite direction. Further investigation is needed to determine the role of late positivity in processing of ambiguous words. Surprisingly, no difference in the N400 amplitude was observed between the targets that were consistent or inconsistent with the meaning of the prime. This is in line with the results of MacGregor and colleagues' study (2015), where the authors assumed that the decay of both meanings after a long interstimulus interval was caused by a competition process.

Conclusion

Results of our ERP study on comprehension of ambiguous words (nouns) show the difference in mechanisms that accompany processing polysemous and homonymous words. In addition, analysis of the interplay between literal, metonymic and metaphorical senses of polysemous words indicates that literal and metonymic senses are close to each other and might share a single mental representation. In contrast, the distance between literal and metaphorical senses is more prominent which is reflected in processing mechanisms similar to that observed for meanings of homonymous words.

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