Does the Semantic Integration of Emotion Words Depend on Emotional Empathy? N400, P600 and Localization Effects for Intentional and Proprioceptive Emotion Words in Sentence Contexts

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Abstract

Empathy with other persons' emotions has been suggested to root in a simulation process involving brain regions that play a crucial role in the production of one's own emotions. The current ERP study combines this approach with an embodied-simulative view of semantics. This view implies that those very brain regions should also be involved in the semantic memory and linguistic comprehension of intentional and proprioceptive emotion words. The relation between cognitive empathy measured by the MET test and the size of the N400 effect occurring when semantic emotions words violate semantic expectations is investigated.

Keywords: empathy, semantic memory, N400, P600, emulative semantics, embodied cognition, simulation theory, mirror neuron system, emotion, proprioception, multifaceted empathy test (MET)

Introduction

The current debate about the neural realization of linguistic meaning and semantic memory can be characterized by two opposing views: According to the abstract-symbolic view, semantic memory is a modular and amodal system. Semantic representations are considered as rather stable, decontextualized mental symbols that are processed in a largely informationally encapsulated way and do not essentially recruit mechanisms from perceptual, motoric or emotional brain processes. Combining various neurolinguistic findings, Friederici (2002) e.g. argues that "semantic processes are mainly subserved by the left temporal region and that the frontal cortex is recruited when strategic and/or memory aspects come into play".

The embodied-simulative view, in contrast, assumes that the processing of linguistic meaning essentially involves perceptual, motoric and emotional brain regions corresponding to the contents of the words to be comprehended. Based on a review of neurobiological data, Pulvermüller (1999) suggests that neural assemblies that pertain to the sensory-motor cortices and are bound by neural synchronization play an important role in understanding the meanings of words and sentences. These cortical sensory-motor action and perception circuits are interdependent in language comprehension. According to Barsalou (2005) semantic representations can be regarded as simulators of sensory-motor and emotional contents. Werning (2012) has coined the notion of Emulative Semantics and proposes a compositional, but non-symbolic recurrent neural network model that generates simulations for semantic representations.

Support for the embodied-simulative view comes from a number of neuro-linguistic studies especially in the domain of action words. Neuroimaging investigations have shown that the linguistic comprehension of verbal stimuli involve motor circuits, i.e. specific motor activations can be found when subjects understand speech sounds, word meanings, semantic categories and sentence structures (Pulvermüller & Fadiga, 2010) involving action words or words associated with actions. FMRI studies (Pulvermüller, 2005) regarding the understanding of action verbs, e.g., hint at a differential top-down activation of motor and pre-motor areas. Martin (2007) reports that the understanding of concrete nouns like *hammer*, for which not only features, but also affordances are salient, results in an activity distributed over the premotor and the visual cortex. Brain areas involved in motor control contribute to neural networks in which verb representations are grounded. Studies on motor deficits such as Parkinson disease, e.g., reveal impairment of patients' action naming (Rodríguez-Ferreiro et al., 2009).

Embodied-simulative accounts of the semantics of action words have been linked to mirror neuron systems. Mirror systems have been reported in humans not only for actions (Rizzolatti et al., 1996), but also for intentional emotions (Bastiaansen et al., 2009; disgust – Wicker et al., 2003; facial expressions – Carr et al., 2003), and proprioceptive emotions (pain – Avenanti et al., 2005; touch – Blakemore et al., 2005). Mirror neuron systems map the perceptions of actions and intentional as well as proprioceptive emotions of an observed person onto the perceiver's own somatosensory, viscero-motor, or motor representations of actions and emotions. Such a mapping is supposed to enable the observer of another person's actions and emotions to feel as if he were performing that action or experiencing that emotion himself. Since mirroring mechanisms may constitute sub-personal instantiations of embodied simulations, Gallese (2003) proposes mirror neuron systems as a neuronal basis of empathy.

These findings and theoretical considerations lay the ground for the current study. If the embodied-simulative view of linguistic meaning also applies to emotion words, the processes underlying empathy with other persons' emotions should be not entirely independent of processes underlying the comprehension of emotion words.

Table 1: **Stimuli**

	CON (congruent)	INCON (incongruent,)	UNREL (unrelated)
INT (intentional emotion)	Als Adrian von seinen hohen Gewinnen an der Börse erfährt, ist er darüber sehr **erfreut**. *When Adrian hears about his high gains on the stock market, he is very **happy** about it.*	… **besorgt**. ***concerned***	…**empört**. ***indignant***
PROP (proprioceptive emotion)	Nachdem Kerstin stundenlang ohne Wasser in der Hitze umherlief, ist sie nun sehr **durstig**. *After Kerstin has been walking around without water in the heat, she is now very **thirsty**.*	…**hungrig**. ***hungry***	…**hellwach**. ***awake***
PHYS (physical control)	Da niemand die Türen jemals geölt hatte, begannen sie nach kurzer Zeit zu **quietschen**. *Since nobody had oiled the doors, they soon began to **squeak.***	…**bollern**. ***thud***	…**tröpfeln**. ***drip***

Furthermore, since the capacity and inclination to empathize with other persons' emotions varies across subjects, we consider it an interesting question whether good emotional empathizers "feel" semantic violations in the context of emotion words more strongly than poor emotional empathizers. One should thus predict that this results in stronger N400 effects.

The examination of the N400 effect in the event-related potentials (ERPs) is a common approach to investigate semantic integration in sentence processing. An N400 is a is a monophasic negativity between 200 and 600 ms after word onset, largest over centro-parietal sites (Kutas & Federmeier, 2011). When comparing semantically expected and unexpected words, observed higher amplitudes of the N400 are discussed to reflect greater demands of semantic integration of an unexpected word at the sentence or the discourse level. Thus, N400 effects are particularly observed for critical words that do not fit into a sentence's context. Recent evidence from sentence processing has shown that the integration of contextual semantic information is dependent on emotional processing (Chwilla et al., 2011; Federmeier & Kutas, 2011; Pinheiro et al., 2013).

Methods

Participants

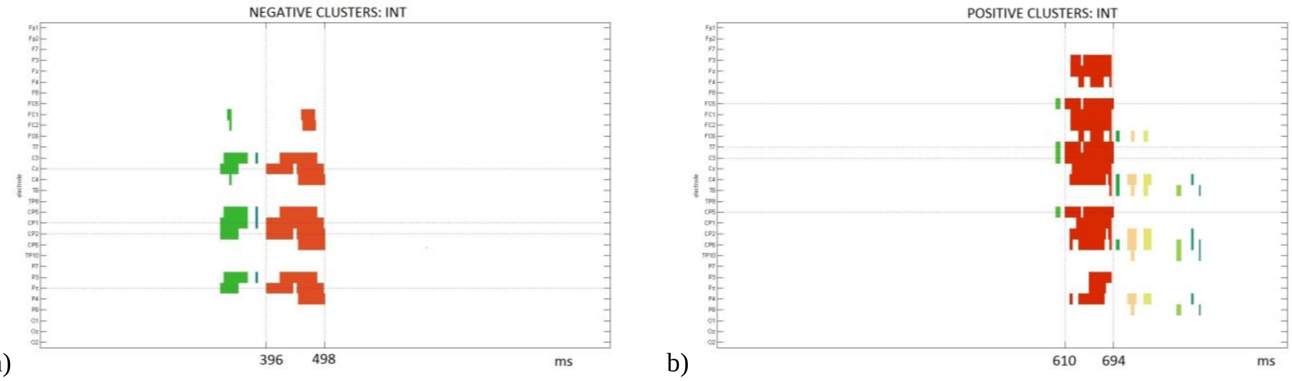
25 female students from the University of Bochum (M=24.19, SD=2.58) volunteered for the experiment. They were compensated with 10€ per hour for their time and effort. They were recruited through local advertisements on the university campus. Only healthy, right-handed women without a history of previous head injury, psychiatric and neurological disorders were included in the study. All were German native speakers, had normal or corrected-to-normal vision and were free of medication.

EEG study

Sentence preparation A total set of 32x3x3x3=864 test sentences and 3x32=96 filler sentences was generated. Each sentence consisted of two clauses conjoined by a coordinating or subordinating conjunction. The target word was always the last word of the sentence and consisted in a medium frequent bisyllabic verb, adjective or participle. The logarithmic frequency of each target word was determined from Wortschatz Leipzig (http://wortschatz.uni-leipzig.de) as the WL index. A WL index of n means that the most frequent German word "der" is 2^n times more frequent than the target word. Following a 3x3 design we introduced the three content categories INT "intentional emotion", PROP "proprioceptive emotion", and PHYS "physical control" and three congruency categories CON "congruent", INCON "incongruent", and UNREL "unrelated" for the target words.

The target words of category INT semantically denoted or lexically entailed an emotional relation between an experiencer and an intentional object. A further grammatical criterion was a verb/adjective valence of at least 2. Words of category PROP semantically denoted or lexically entailed a proprioceptive feeling of an experiencer. Grammatically, these words had either a verb/adjective valence of less than 2 or were causatives resulting in a proprioceptive feeling. Category PHYS was designed as a control with non-mental target words. The target words for each of the content categories were grouped into triplets with one word for each of the three congruency categories (32 triplets for INT, PROP and PHYS each). For each triplet three different, but contentwise similar sentential contexts of the above mentioned two-clause structure were created such that the sentences completed by the word of condition CON would describe a semantically congruent and plausible scenario. The word of condition INCON was closely semantically related to that of condition CON (being typically an antonym or contrastive word), but would make each of the three sentential contexts semantically incongruent and implausible. The word of condition UNREL was not or only distantly semantically related to that of condition CON and would make each of the three sentential contexts grossly semantically incongruent and implausible. By combination altogether 9 sentences were created from each triplet and the three contexts. This allowed us to present the sentences to the subjects in random selection and order such that each subject saw all three target words of each triplet and all three of the corresponding sentential contexts without any repetition of either the target words or the contexts. Priming effects were thus avoided.

There were no significant differences in logarithmic frequency of the target words across the 9 conditions of the



a) b)

Figure 1. **Cluster-based permutation test for intentional emotion words**. The test compares the congruency conditions UNREL to CON in the content condition INT for all channels and each 2ms segment (α=0.025). The resulting significant clusters are marked red a) Negative cluster corresponding to an N400 effect with onset at 396ms and offset at 498ms (p=0.0096). b) Positive cluster corresponding to a P600 effect with onset at 610ms and offset at 694ms (p=0.0048).

3x3 design (M=13.49, SD=2.26). The word classes were balanced between verbs, adjectives, and participles. The reason for the filler sentences was to balance semantically congruent (CON and Fillers) and incongruent (INCON and UNREL) scenarios. Each subject saw 288 test sentences and 96 filler sentences, i.e. altogether 384 sentences. See Tab. 1.

Sentence Task Subjects viewed whole sentences, presented in Presentation software (Neurobehavioral Systems Inc., Albany, CA, USA) on the screen in front of them, in small chunks of words at a time for 500ms each. The sentence started after the presentation of a centered fixation cross that stayed on the screen for 1000ms. The words were presented in black letters on a grey background in the center of the screen. There was an inter-stimulus interval between the chunks of 50ms, which showed a blank screen only. The last word was always the target word and determined the onset of the N400 measure epoch. After 33% of the sentences, a question mark appeared 2000ms after the offset of the target word which required the subject to press a button ("yes" or "no") for whether they considered the sentence to be sensible or not. The filler sentences mentioned above were necessary to enable an approximately equal number of button presses. The question mark was followed by a 2000ms blank screen until the next sentence started. The main purpose of the question served to keep participants engaged and alert during passive viewing.

Background Measures

Multifaceted empathy test (MET) As a measure of empathy, the MET depicts 40 different photographs of various people in emotionally charged situations, with a varying degree of expression on their faces (Dziobek, 2008). In the computer task, each picture is presented three times with three different questions. Cognitive empathy is assessed by the question "How does the person feel?". By pressing a number from one to four, the subject has to choose one of four possible emotional states, only one of which is defined as correct. The maximum score is 40 points. Two kinds of affective empathy are measured. Explicit empathy is assessed by the question "How much do you compassionate with this person?" and implicit empathy is compiled by the question "How strongly aroused are you by the picture". In both conditions, subjects are asked to rate their emotional engaging on a nine-point scale ranging from 1 (not at all) to 9 (very much). The implicit empathy measure reduces the subject's tendency to answer socially desirable. The maximum scores for both affective empathy measures are 9 points each.

Procedure

Participants were seated comfortably in a chair, at a distance of 75cm from the screen in a sound-proof and electrically shielded room with ambient lighting. Upon arrival, they signed informed consent, completed the Edinburgh handedness test and the eating disorders subtests of the DIPS (Diagnostisches Interview bei psychischen Störungen, reported elsewhere). Electrodes were applied to the scalp. After receiving task instructions, a short practice task of five training trials was introduced to ascertain comprehension of the task requirements. A total of 384 sentences, presented in a randomized order and split up into three equal presentation blocks, were presented on the screen. A keyboard with two response buttons was positioned in front of the subjects on the table. In between the blocks, participants had resting periods of at least 5 minutes in order to recover from fatigue and concentration loss. The total duration of the experimental task was 1 hour. By the end of the recording procedure, subjects completed the multifaceted empathy test (MET) offline.

Electroencephalography Recording and Data Analysis The analysis is based on 30 active electrode channels that recorded an electroencephalogram (EEG) from the subjects' scalp surface with a BrainAmp acticap EEG recording system (BrainAmps amplifier, München) according to the international 10-20 system. Four additional electrodes measured participants' electrooculogramm (EOG) for both vertical and horizontal eye movements for later removal of eye movement artifacts. The reference electrode was placed in the position of the FCz and AFz served as ground electrode. The sampling rate was 500Hz and impedance was lowered to below 5kΩ. The EEG data were analyzed using BrainVision Analyzer 2.0 (BrainVision, München). After recording with a 0.5305–70Hz online filter, the data were filtered off-line through a 0.5305–30Hz bandpass zero phase Butterworth filter. Afterwards eye-blink artifacts were removed by an independent component analysis (ICA) which was performed for each subject. The reference electrode was offline re-referenced retrospectively to the linked mastoids comprising TP9 and TP10. An automatic artifact rejection removed all trials with amplitudes above 90 µV and below -90 µV. Segments from 200 ms pre-target onset until 1000 ms post-onset were separately extracted and averaged for every subject and for each of the 3x3 conditions {INT, PROP, PHYS}×{CON, INCON, UNREL}.

a) b) c)

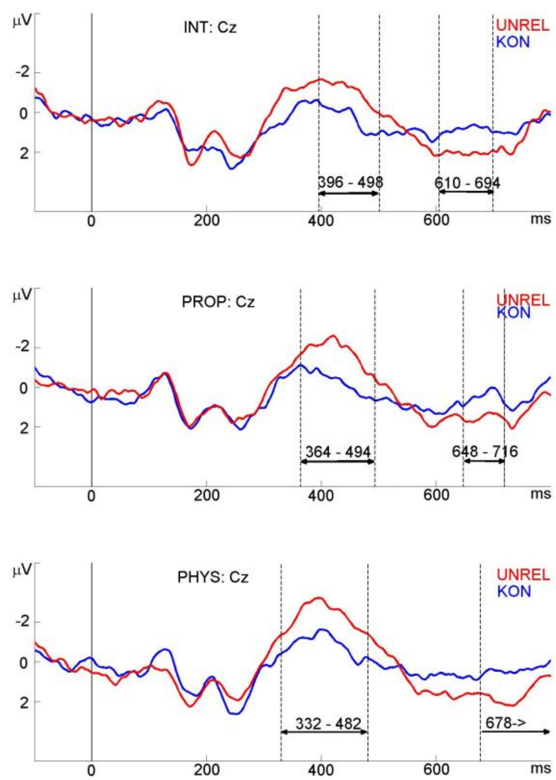


Figure 2. **Grand average ERP waveforms for the electrode Cz**. The two congruency conditions UNREL and CON are compared. The dotted lines mark the onsets and offsets of the N400 and, respectively, the P600 effects according to the cluster based permutation test. a) Intentional emotion words (INT). Cluster significance: p(N400)=0.0096, p(P600)=0.0048. b) Proprioceptive emotion words (PROP). Cluster significance: p(N400)=0.0004, p(P600)=0.0325. c) Physical controls (PHYS). Cluster significance: p(N400)= 0.0016, p(P600)= 0.0072.

Results

Onset and offset of N400 and P600

In order to determine the onset and offset of N400 and P600 effects, we compared the ERPs in the congruent condition against the ERPs in the unrelated condition for all three content conditions. The onset and the offset of the N400 and P600 were determined by a resampling procedure, the cluster-based permutation test: The averaged ERPs for each subject in the CON and UNREL condition were collected in a single set, which was then randomly partitioned into two equally sized subsets. The data-points (time x channel) were compared between the partitioned sets by a dependent t-test. The significantly different – $\alpha=0.025$ (The significance level of 0.05 was Bonferroni corrected by a factor 2 since both negative and positive clusters were of interest) – data points were then clustered according to temporal-spatial adjacency. The cluster-level statistics was calculated by taking the sum over the t-values for each cluster. This procedure was repeated 10,000 times. The p-values of the observed cluster-level statistics were estimated as the proportion of partitions that resulted in a higher cluster-level statistics than the observed one (Maris & Oostenveld, 2007).

The resampling procedure revealed the positive and negative clusters, i.e. collections of time-channel points where the measured amplitude in the UNREL condition was significantly higher (resp. lower) than in the CON condition. The onset of the cluster was taken to be the first time point contained in the cluster, whereas the offset was taken as the last time point in the cluster. The results of the cluster-based permutation test for condition INT is shown in Fig.1. Fig. 2 displays the grand averages on electrode Cz for all three content conditions with onsets, offsets and p-values for the N400 and P600 clusters determined by the cluster-based permutation test. Fig. 3 and Fig. 4 show the topographical distribution of the N400 and P600 effects.

MET scores and N400

We were interested whether subjects' MET scores correlate with the effect-sizes of the N400 effects. To gain insight on

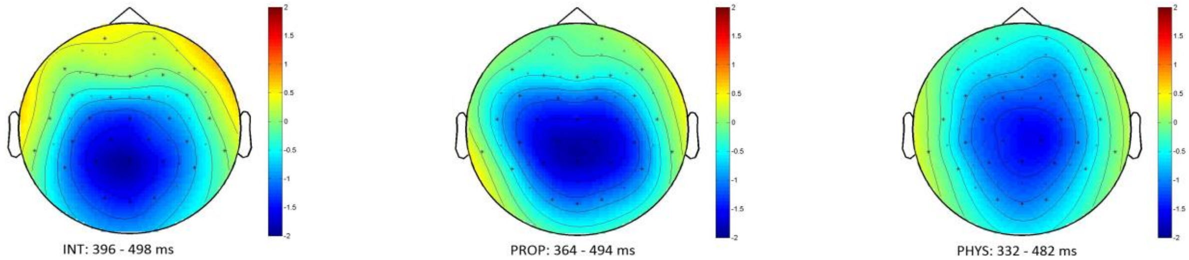


Figure 3. **Topography of the N400 effects.** The topographical mapping shows the difference between the congruency conditions UNREL and CON for the three content conditions averaged between onset and offset of the N400 effect according to the cluster-based permutation test. In all three content conditions the N400 effect has a centro-parietal extension.

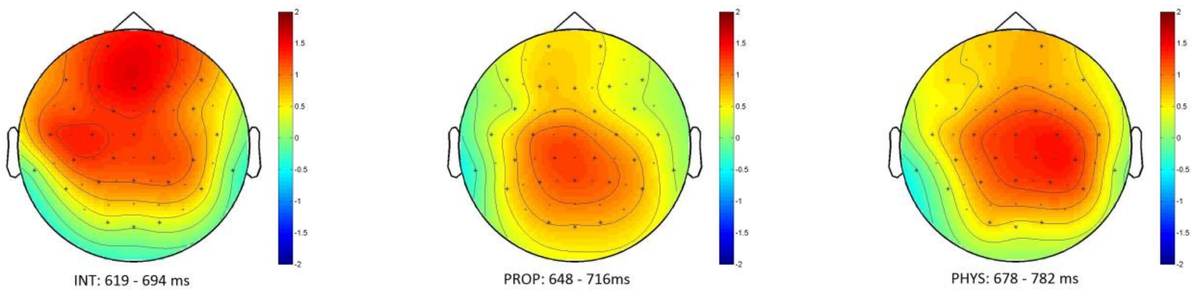


Figure 4. **Topography of the P600 effects.** The topographical mapping shows the difference between the congruency conditions UNREL and CON for the three content conditions averaged between onset and offset of the P600 effect according to the cluster-based permutation test. a) For intentional emotion words (INT) the P600 effect has a medial-frontal focus. b) For proprioceptive emotion words (PROP) the P600 effect has a centro-parietal focus. c) In the physical control condition, the P600 effect has a centro-parietal focus with a right hemispheric dominance.

a) b)

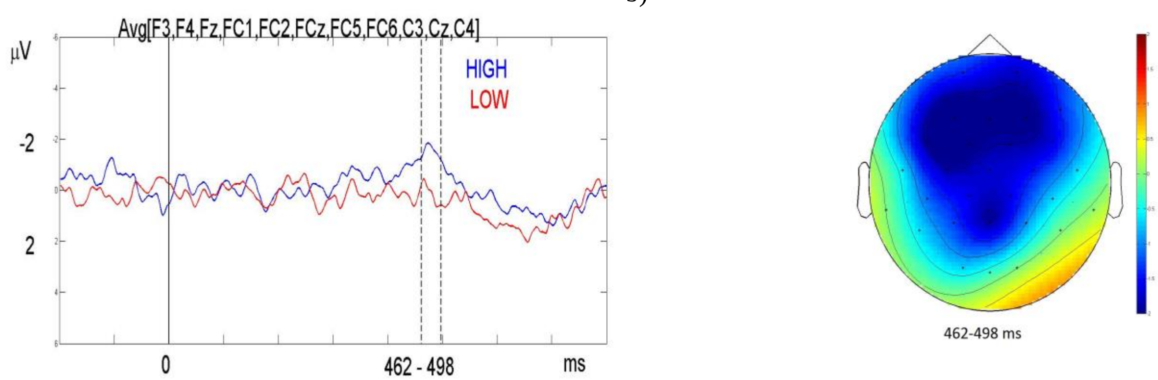


Figure 5. **Comparing the N400 effect for intentional emotion words on the median split between HIGH and LOW cognitive empathizers**. a) The difference between the congruency conditions UNREL and CON for intentional emotion words for the HIGH and LOW cognitive empathy group averaged over electrodes in the significant cluster. b) Topographical mapping of the differences between the HIGH and the LOW group (HIGH - LOW) for the N400 effect on the time interval determined by the cluster-based permutation test. The effect difference between HIGH and LOW cognitive empathizers peaks in the fronto-central region.

this matter, we did a median split of the tested group of subjects with respect to the three MET-scores: The subjects were split into HIGH (N=12) and LOW (N=13). We conducted a cluster-based permutation test to find out the significant differences between the HIGH cognitive empathy and the LOW cognitive empathy group in the time window of the main N400 effect for condition INT (396-498ms).

The cluster-based permutation test confirmed that the HIGH cognitive empathy group has a significantly ($\alpha=0.05$, $p=0.0286$) stronger N400-effect than the LOW cognitive empathy group in the time interval 462-498ms for condition INT, see Fig. 5 Due to space limitation the significant findings regarding proprioceptive emotion words are not discussed here.

Discussion

As argued above, the embodied-simulative view of meaning predicts that subjects who have a higher capacity to empathize with the emotions of other persons should be more sensitive also to semantic violations that occur when an emotion word is embedded in an incongruent or even unrelated sentence context. This stronger sensitivity should correlate with a stronger N400 effect, which is a widely acknowledged measure for the violation of semantic expectations. As our study revealed, subjects with a high MET score for cognitive empathy with emotions, indeed, show a significantly stronger N400 effect when an intentional emotion word is embedded in a semantically unrelated sentence context than those with a low score. This difference is strongest in fronto-central regions of the brain.

Aside from these results interesting localization differences in the P600 effects were found between intentional and proprioceptive emotion words and the physical control condition while only marginal localization differences occurred for the N400 effects. Due to space limits a discussion of those will be deferred.

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