Sex Differentiates the STROOP-Effect in Emotional Speech: ERP Evidence

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Abstract

The present study investigated the processing of emotional speech in men and women. The stimulus material consisted of words with positive, neutral or negative meaning that were spoken with either congruent or incongruent emotional prosody. In one task, participants judged the emotional prosody while ignoring the word meaning, in another task participants judged the emotional word meaning while ignoring the prosody. The event related potentials (ERPs) revealed an interaction of emotional prosody and word meaning only in female participants. Incongruent trials elicited an enhanced N400 amplitude as compared to congruent trials. Male participants failed to show an interaction. Rather, ERPs revealed independent effects for word meaning and emotional prosody, suggesting that men process both types of emotional information independently.

1. Introduction

In every day speech, emotions can be expressed via different communication channels. Beside words, a speaker also uses speech melody, referred to as prosody, to express emotions. However, emotional perception seems to differ between men and women. Tasks that require the recognition of emotions from verbal and nonverbal cues revealed a small female superiority [1,2]. Furthermore, in a recent study [3] we found sex differences in the time course of the interaction between emotional prosody and word meaning during language comprehension. In a cross-modal priming experiment, female participants showed an influence of emotional prosody on word processing with a small (200ms) interval between the emotional-prosodic prime and the visual target word. When there was congruence between the emotional prosody of the prime and the emotional valence of the target word, the N400 amplitude in the event related potential (ERP) was smaller as in case of incongruence. A similar N400 effect in men occurred only with a longer (750ms) interval between prime and target.

The aim of the present study was two-fold. First, we wanted to investigate sex differences in the role of emotional prosody during speech processing rather than measuring the influence of emotional prosody on a visual target word. Second, we were interested in whether prosody or word meaning would dominate emotional processing in men and women.

2. Methods

2.1. Subjects

Thirty-six subjects participated in the study. Because of eye and movement artifacts in the electroencephalogram (EEG), only 32 subjects, were included in the data analysis. Sixteen were female with a mean age of 22.9 (sd 2.3) and 16 were male with a mean age of 23.5 (sd 2.9).

2.2. Material

The stimulus material consisted of 74 positive, 74 neutral and 74 negative inflected German verbs (e.g., geliebt, geparkt, gehasst; loved, parked, hated). Word frequency did not differ between the three valence conditions [4]. A female speaker of standard German produced all words with happy, neutral and angry prosody. Words were taped with a DAT recorder and digitized at a 16-bit/44.1 kHz sampling rate. The stimulus material was divided into two lists with 37 positive, 37 neutral and 37 negative words spoken in each of the three prosodic conditions. Both lists were presented to each subject with either a semantic or a prosodic instruction. Order of lists and tasks was counterbalanced across subjects.

2.3. Procedure

Participants were tested individually in a sound attenuated electrically shielded chamber. They sat in a comfortable chair facing a computer monitor at a distance of 1.15 meters. An experimental session was divided into two blocks. In one block participants had to judge a word's prosody as positive, neutral or negative. In the other block they were asked to judge the emotional meaning of a word as positive, neutral or negative. In both tasks participants were asked to ignore the interfering information. Responses were given by pressing one of three buttons of a response box as fast and as accurately as possible. To prevent baseline artifacts in the ERP, the time interval between words was temporally gittered with 3000ms, 3100ms and 3200 for a third of the trials respectively.

2.4. ERP Recording and Analysis

The EEG was recorded from 58 electrodes mounted in an elastic cap according to the 10-20 system. The reference was placed on the tip of the nose. In order to control for eye movements an electrooculogram was recorded using 4 electrodes. Trials containing eye blinks or movement artifacts were omitted from the data analysis. ERP averages were computed with a 150ms pre-stimulus baseline and a 1000ms time window. Grand averages are smoothed with an 8-Hz low pass filter for illustration only.

For statistical analysis electrodes were grouped into 4 regions of interest: left anterior (F7, F5, F3, FT7, FC5, FC3, T7, C5, C3), right anterior (F8, F6, F4, FT8, FC6, FC4, T8, C6, C4), left posterior (TP7, CP5, CP3, P7, P5, P3, PO7, PO3, O1) right posterior (TP8, CP6, CP4, P8, P6, P4, PO8, PO4, O2). The p-values for post hoc comparisons were corrected using a modified Bonferroni procedure [5]. Because of limited space only the relevant results will be reported.

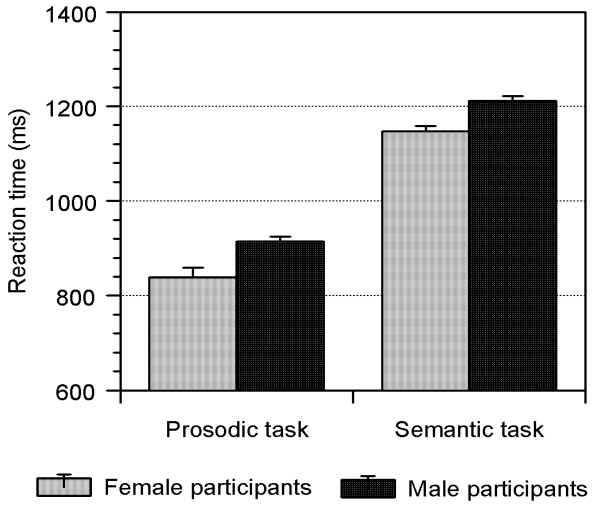

Figure 1: Reaction time (± standard error).

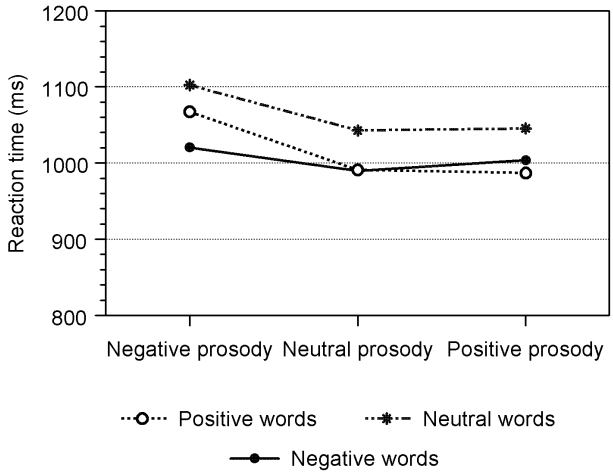

Figure 2: Reaction time averaged across task and sex.

3. Results

3.1. Behavioral Results

We conducted an analysis of variance with Sex as between subjects factor and Task (prosodic, semantic), Word Meaning (positive, neutral, negative) and Word Prosody (happy, neutral, angry) as repeated factors. Single comparisons are reported when main effects or interactions with an experimental factor reached significance.

The reaction time data revealed faster responses in female than in male participants ($F(1,30) = 4.27$, $p < .05$). Furthermore, response latencies for both male and female participants were shorter during the prosodic than during the semantic task ($F(1,30) = 321.52$, $p < .05$). Independent of task there was an interaction between word meaning and word prosody. Words that were spoken with happy or angry prosody elicited tendentially and significantly shorter response latencies when word meaning was congruent as compared to incongruent (see Table 1 and Figure 2). Regardless of the emotional prosody, neutral words elicited longer response latencies than positive and negative words.

Table 1: Statistical analysis of the reaction time data

Word Prosody	Word Meaning		Statistics
Positive	Pos	Neu	F(1,30) = 38.29, p < .0001
		Neg	F(1,30) = 3.42, p = .07
Neutral	Neu	Pos	F(1,30) = 39.89, p < . 0001
		Neg	F(1,30) = 36.99, p < . 0001
Negative	Neg	Pos	F(1,30) = 30.4, p < . 0001
		Neu	F(1,30) = 65.59, p < . 0001

The accuracy data revealed no sex differences. Interference was found for the semantic but not for the prosodic task. During the semantic task, congruent trials were responded more accurately than incongruent trials. However, not all comparisons revealed significant effects (see Table 2).

Table 2: Statistical analysis of the accuracy data

Word Meaning	Word Prosody		Statistics
Positive	Pos	Neu	F(1,30) = 8.61, p < .01
		Neg	F(1,30) = 10.06, p < .01
Neutral	Neu	Pos	p > .1
		Neg	F(1,30) = 8.45, p < .01
Negative	Neg	Pos	F(1,30) = 15.99, p < .0001
		Neu	p > .1

3.2. ERP Results

Because of differences in the ERP waveforms between the two tasks we conducted separate analysis of variance for each task with Sex as between subjects factor and Word Meaning (positive, neutral, negative), Word Prosody (happy, neutral, angry), Hemisphere (left, right) and AP (anterior/posterior) as repeated factors. Single comparisons are reported when main effects or interactions with an experimental factor reached significance.

3.2.1. Prosodic Task

N400 (300-500ms). As illustrated in Figure 3, female participants showed an interaction between the emotional prosody of a word and its meaning. The N400 amplitude for angrily and happily spoken words was smaller when word valence was congruent (i.e., emotional match) as compared to when it was incongruent (i.e., emotional mismatch). However, this difference was not significant for all comparisons (see Table 3). Furthermore, there were no differences in the N400 amplitude for neutrally spoken words. To analyze whether the N400 effect reflects an increase or a decrease in activity due to the interactive prosodic and word processing, a single comparison between the neutral match condition and the emotional mismatch conditions was conducted. The fact that there was no significant difference [$p > .1$] suggests that women do not pay additional processing costs on incongruent trials but rather profit in processing from congruence between emotional prosody and word valence.

In contrast to female participants, male participants did not show congruence effects reflected in the N400 amplitude.

However, a prosodic effect over anterior regions suggests that there is a brain region in both sexes that processes emotional prosody independently. At anterior electrodes, neutral prosody elicited a temporarily extended N400 and was therefore significantly more negative as compared to happy [F(1,30)=19.76, p<.0001] and tendentially more negative as compared to angry prosody [F(1,30)=4.48, p=.04].

Table 3: Statistical analysis of the ERP data for the prosodic task

Word Prosody	Word Meaning		Statistics
Positive	Pos	Neu	F(1,30) = 8.96, p < .01
		Neg	F(1,30) = 4.05, p = .06
Neutral	Neu	Pos	p > .1
		Neg	p > .1
Negative	Neg	Pos	F(1,30) = 6.16, p < . 03
		Neu	p > .1

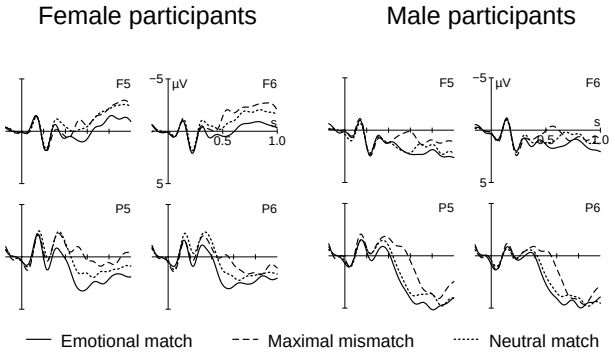

Figure 3: ERPs for the prosodic task.

P300 (500-700ms). Following the N400 there was a main effect for word meaning. Neutral words elicited a smaller P300 amplitude as compared to positive [F(1,30)=8.11, p<.01] and negative words [F(1,30)=7.54, p<.01]. Similarily, neutral prosody elicited smaller P300 amplitudes than angry [F(1,30)=11.68, p<.0001] and happy prosody [F(1,30)=19.53, p<.0001].

3.2.2. Semantic Task

N400 (300-700ms). Again women but not men show an interaction between word meaning and prosody. In women, words spoken with a happy or angry voice elicited a smaller N400 when word valence was congruent than when it was incongruent. Congruency had no influence on trials spoken with a neutral voice. Furthermore, a single comparison between the neutral match and the emotional mismatch conditions revealed no significant amplitude differences [p > .1]. This indicates that the N400 interference effect in women does not reflect an increase in activity for the incongruence condition but rather a decrease in activity when word and prosodic information are congruent. In contrast, men did not show any influence of word prosody on the N400 amplitude. Rather the N400 in men indicated independent word valence processing. At left hemisphere sites, neutral [F(1,15)=12.22, p<.01] and negative words [F(1,15)=10.89, p<.01] elicited a larger N400 than positive words. Negative and neutral words did not differ [p > .1].

Late positivity (700-900ms). The interaction between emotional prosody and word valence in females reported for the N400 extended into a time window between 700 and 900ms. As post hoc comparisons revealed results that were comparable to the N400 effect, they will not be reported here. Furthermore, a prosodic effect that was independent of sex

Table 4: Statistical analysis of the ERP data for the semantic task

Word Prosody	Word Meaning		Statistics
Positive	Pos	Neu	F(1,30) = 3.64, p = .08
		Neg	F(1,30) = 31.85, p = .0001
Neutral	Neu	Pos	p > .1
		Neg	p > .1
Negative	Neg	Pos	F(1,30) = 7.89, p < . 03
		Neu	F(1,30) = 8.14, p < . 03

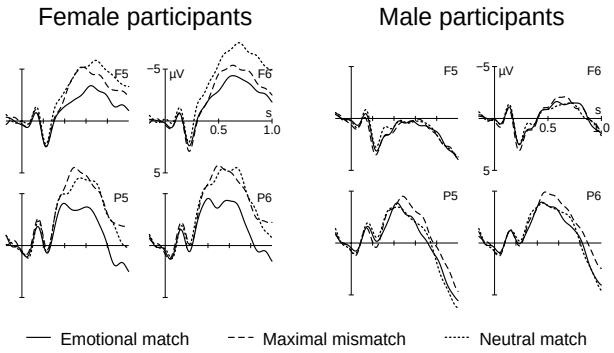

Figure 4: ERPs for the semantic task.

suggests that between 700 and 900ms both sexes process emotional-prosodic information. At anterior sites, happy and angry prosody elicited a smaller positivity as compared to neutral prosody [pos-neu, F(1,30)=10.82, p<.01; neg-neu, F(1,30)=11.42, p<.01; pos-neg, p>.1]. At posterior sites, angry prosody elicited a smaller positivity as compared to happy and neutral prosody [pos-neg, F(1,30)=7.86, p<.01; neu-neg, F(1,30)=13.19, p<.001; pos-neu, F(1,30)=3.34, p=.078].

4. Discussion

The present findings confirm that there are sex differences in the processing of emotional speech. ERPs revealed an interaction between the emotional prosody of a word and its meaning only for female but not for male participants. Words that were spoken with congruent prosody elicited a smaller N400 as compared to words with incongruent prosody. This effect was more salient and extended over a longer time interval during the semantic as compared to the prosodic task. Consequently, prosody has a stronger impact on the word valence judgment than vice versa suggesting that in women prosody rather than word meaning dominates the processing of emotions in speech.

In contrast to female participants, males showed independent processing of prosody and word meaning.

During the prosodic task the N400 was sensitive to the emotional prosody of a word, whereas during the semantic task the N400 was sensitive to the emotional meaning of a word. Task irrelevant stimulus information elicited effects following the N400. Although the ERP of male participants revealed no interaction between the two stimulus dimensions, there was significant interference in the behavioral data. These behavioral effects might reflect interference during response preparation. The independent processing of both word meaning and prosody as reflected in the ERP could lead to the activation of different emotional tags. At incongruent trials, these emotional tags might cause behavioral interference by activating the appropriate as well as the inappropriate response. Output interference in both sexes has also been reported for the classic word-color-STROOP task [6].

Although male participants were very well able to adjust processing according to the task, they failed to show better task performance than female participants. On the contrary, with no sex differences in accuracy women made faster emotional judgments than men. Furthermore, the N400 effect in women was not due to inhibition in case of incongruence. Rather, congruence between prosody and word meaning facilitated processing. Therefore, it seems that the inability of women to ignore task irrelevant information was no disadvantage in terms of task performance. Moreover, they were more efficient than man in making their emotional judgment.

Performance differences between men and women in emotional tasks have already been reported in the literature. For example, Doherty et al. [7] found higher emotional contagion in women than in men. Further studies [1,8] revealed that women judge the meaning of words as more emotional than men. Similarly, a meta-analysis by Hall [2] suggests that women outperform men in the recognition of emotions from voices, faces and gestures. The present study extends these findings of performance differences to differences in the processing of emotional speech. Women integrate emotional information from prosody and words earlier and more automatically than men.

5. References

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