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ERP Evidence of a Stroop-Like Effect in Emotional Speech Related to Social Anhedonia

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Abstract. The present study investigated the ERP correlates of the integration of emotional prosody to the emotional meaning of a spoken word. Thirty-four nonclinical participants listened to negative and positive words that were spoken with an angry or happy prosody and classified the emotional valence of the word meaning while ignoring emotional prosody. Social anhedonia was also self-rated by the subjects. Compared to congruent trials, incongruent ones elicited slower and less accurate behavioral responses, and a smaller P300 component at the brain response level. The present data suggest that vocal emotional information is salient enough to be integrated early in verbal processing. The P300 amplitude modulation by the prosody-meaning congruency positively correlated with the social anhedonia score, suggesting that the sensitivity of the electrical brain response to emotional prosody increased with social anhedonia. Interpretations of this result in terms of emotional processing in social anhedonia are discussed.

Keywords: social anhedonia, emotional Stroop, ERP, emotional prosody, P300

For emotional communication, humans use different channels that can either be verbal (emotional meaning) or nonverbal (facial or vocal affect). Successful social interactions require an integration of information from these two channels conveyed simultaneously in spoken utterances. Within the scope of speech perception, irony and sarcasm comprehension implies the detection and the resolution of a conflict between the meaning of a sentence and the emotional valence of the speaker’s voice. The processing of emotional prosody has been investigated in a number of neuroimaging and patient studies (see Schirmer & Kotz, 2006, for a review). Several studies used ERP on various paradigms to explore when emotional prosody processing interacts with the emotional meaning of a word but their results remain heterogeneous. Results can be divided between studies showing an early integration of emotional prosody and emotional meaning of a word, between 200 and 300 ms post stimulus onset, and studies showing a later integration of those two channels, from 400 ms to 1,500 ms. The first result showing an early integration came from a priming paradigm: primes were spoken emotion names and targets were emotional vocalizations (Bostanov & Kotchoubey, 2004). The incongruence between primes and targets led to a larger N300 amplitude. Another study has even demonstrated an earlier interaction between lexical and prosodic emotional cues on a multimodal facilitation paradigm: the P200 amplitude was smaller when participants were exposed to emotional signal containing congruous prosodic and lexical information than when they were exposed to prosodic only signals (Paulmann, Jessen, & Kotz, 2009). The second line of research that demonstrated later interaction between emotional prosody and semantics is based on a variant of the classical Stroop paradigm (MacLeod, 1991; Stroop, 1935): the emotional semantics-prosody Stroop-like paradigm. Participants have to judge the emotional valence of a spoken word while ignoring the emotional tone of voice with which it is pronounced. Several studies have shown that emotional prosody automatically interferes with verbal emotional processing: emotionally incongruent stimuli lead to reduced behavioral performances (i.e., response time and error rate) when compared to congruent stimuli (Nygaard &
n hypothesis that the P300 will be smaller for incongruent gruence between emotional prosody and semantics in our hypothesis that P300 amplitude was modulated by the con-
salient ones (Szucs et al., 2009). Given that emotional prosy was larger when word meaning and prosody were incon-
gruent than when they were congruent. In these two studies, no modulation of P300 or earlier components was reported in any group. It is arguable that the discrepancy found in these different studies came from the fact that they used dif-
ferent paradigms. So a replication of early interactions found in priming and facilitation paradigms on a Stroop-
like paradigm is necessary to convincingly validate the hypothesis that emotional prosody is a highly salient in-
formation leading to an early interference with language pro-
cessing. The present study attempted to validate this early interference hypothesis on an emotional semantics-prosody Stroop-like paradigm by examining the entire waveform and time course of the integration of emotional prosody to language processing, from the presentation of stimulus to response. The study will particularly focus of one early ERP component that has been extensively studied in non-
emotional Stroop-like paradigms, the P300. It is a well-rup-
licated positive component occurring around 300 ms post auditory or visual stimuli, which is thought to reflect, through its different subcomponents, the attentional and information processing load elicited by the stimulus (Pol-
ich, 2007). Some studies have demonstrated a decreased P300 amplitude for incongruous condition compared to the congruous condition in nonemotional Stroop-like para-
digms (Ilan & Polich, 1999; Shen, 2006; Szucs, Soltesz, & White, 2009). These modulations of P300 amplitude by congruency are often interpreted as the sign that interfer-
ence between the two conflicting information occurs at an encoding stage of processing, prior to response preparation. In contrast, later modulations of the ERP waveform in the absence of modulations of earlier components, such as the P300, are generally interpreted as the sign that interference between the two conflicting information occurs after the stimulus evaluation and decision making, during the prepara-
tion of response, with a parallel activation of the correct and the incorrect responses (Liotti, Woldorff, Perez, & Mayberg, 2000; Markela-Lerenc et al., 2009; West, 2003). Some authors have suggested that the time course of ERP modulation in Stroop-like paradigms may depend on the salience of conflicting information: salient informa-
tion may modulate earlier components of ERP than less salient ones (Szucs et al., 2009). Given that emotional prosy is likely to be a salient information, we made the hypothesis that P300 amplitude was modulated by the congruence between emotional prosody and semantics in our emotional semantics-prosody Stroop-like paradigm, rather than later components. More precisely, we made the hypothesis that the P300 will be smaller for incongruent items than for congruent ones. P300 amplitude varies as a function of perceptual discrimination difficulty on oddball paradigms, with a lower amplitude found for the discrimi-
nation of difficult targets compared to easy ones (Hagen, Gatherwright, Lopez, & Polich, 2006; Kim, Kim, Yoon, & Jung, 2008; Kimura, Katayama, & Murohashi, 2008). Because emotional semantics should be harder to identify for incongruent items compared to congruent ones due to an early integration of emotional prosody in language pro-
cessing, the P300 amplitude should decrease when emo-
tional prosody is incompatible with emotional semantics.

It has been suggested that the use of emotional prosody for language processing is modulated by interindividual variables (Schirmer & Kotz, 2006). In this study, we will focus on one particular interindividual variable, social anhedonia, which has been extensively linked with the pro-
cessing of emotional conflicts (Kerns, 2009). The psycho-
pathological construct of anhedonia is defined as a diminished capacity to experience pleasant emotions for social and physical stimuli (Chapman, Chapman, & Raulin, 1976). Precisely, social anhedonia comes from a diminished experience of positive emotions from social-interpersonal sources like talking, socializing, or being with people in other ways. Social anhedonia has a great psycho-
pathological importance because it has been linked with several psychiatric conditions such as schizophrenia (Blanchard, Horan, & Brown, 2001; Ritsner, Arbitman, & Lisker, 2011; Velthorst et al., 2009) and schizotypy (Blanchard, Collins, Aghaei, Leung, & Cohen, 2011; Horan, Brown, & Blanchard, 2007; Rey, Jouvent, & Dubal, 2009). There is a growing body of evidence that anhedonia, particularly in its social form, could be related to abnormalities in emotional processing in clinical and nonclinical populations. Nonclinical individuals with high level of social anhedonia demonstrate a deficit in the executive con-
tral of socially relevant emotional information (Tully, Lincoln, & Hooker, 2012). For instance, participants with a high level of social anhedonia (who scored 2 standard deviations above the same-gender sample mean on the Chapman’s Revised Social Anhedonia Scale) exhibited an increased sensitivity to affectively valenced targets as com-
pared to controls on a word pronunciation task, whereas they did not exhibit increased semantic priming (Kerns & Berenbaum, 2000). In the same line, people with elevated social anhedonia (with the same criterion as defined above) exhibited poor controlled evaluative processing of emotion on a primed evaluation task because their emotional judg-
ments on target words were more influenced by primes’ valence than comparison participants. This effect was spe-
cific to the emotional dimension of the controlled evalu-
aive processing as participants exhibited neither poorer cognitive control on a Stroop color-naming task nor increased semantic priming on a semantic priming task (Martin & Kerns, 2010). Moreover, this failure to counter-
act the influence of the prime’s emotional content in evalu-
ating the target was specific to social anhedonia, because it was absent in participants with elevated percep-
tual aberration and magical ideation, which is another mea-
sure of an increased risk of future schizophrenia-spectrum disorders focusing on psychotic-like distortions and unusual
beliefs (Martin, Cicero, & Kerns, 2011). Among psychiatric populations, it was shown that schizophrenic patients with anhedonia are more reactive to emotional stimuli than patients without anhedonia. For example, anhedonic patients with schizophrenia were found to be sensitive to negative facial affect on a subliminal affective priming task, whereas patients without affect symptoms were not (Suslow, Roestel, & Arolt, 2003). In this study, anhedonia measurement was also positively correlated with subliminal sensitivity to negative emotional faces. Anhedonic patients with schizophrenia had better performance in the detection of a positive face among several neutral faces than nonanhedonic patients and anhedonia measurement positively correlated with detection speed of positive faces compared to neutral faces, as if spatial detection of positive faces became more efficient with increasing anhedonia (Suslow, Roestel, Ohrmann, & Arolt, 2003). Sensitivity to emotional prosodic cues increased with the level of social anhedonia in participants with schizophrenia on an emotional semantics-prosody Stroop-like paradigm (Roux et al., 2010). Several studies have investigated the relation between brain electrical activity and anhedonia in nonclinical populations. They used standard oddball paradigms with nonemotional stimuli and reported reduced P300 amplitude in participants with high level of anhedonia (Franken, Van Strien, & Nijs, 2006) and particularly in participants with high level of social anhedonia (Nuchponsai, Arakaki, Langman, & Ogura, 1999) compared to individuals with low level of anhedonia: these results suggest a relation between anhedonia and attentional deficits. Individuals with high level of anhedonia also exhibited a smaller P300 compared to nonanhedonic participants on an Eriksen flanker task (Dubal, Pierson, & Jouvent, 2000). The negative correlation of P300 amplitude and social anhedonia was also confirmed in individuals with an increased risk for a first psychotic episode (van Tricht et al., 2010). Other authors have found a positive correlation between the reduction of P50 amplitude on a stimulus pair paradigm and social anhedonia in schizophrenia, thus suggesting abnormalities in early somatosensory information processing in social anhedonia (Arnfred & Chen, 2004). To our knowledge, no study has yet explored the relation between social anhedonia and ERP during emotional processing. The exploratory objective of the present study is to evaluate the putative relation between the level of self-reported social anhedonia and brain electrical activity during an emotional semantics-prosody Stroop-like paradigm. We hypothesize that the behavioral and neural influence of emotional prosody on the emotional judgment about the meaning of a word will increase with the level of social anhedonia, suggesting a failure in the executive control of emotional information in social anhedonia. At the group level, the reaction time and error rate differences between incongruent and congruent items should be positively correlated with the level of social anhedonia. Moreover, the neural signature of the emotional conflict between the meaning of a word and its prosody should also increase with social anhedonia.

### Material and Methods

#### Subjects

Thirty-four subjects participated in the study (see Table 1). The exclusion criteria were history of hearing loss, neurological or psychiatric illness, and head trauma with a loss of consciousness longer than 10 min. All participants were native French speakers. After receiving a complete description of the study, participants signed a written informed consent. They were paid for their participation. The study was approved by the local ethics committee.

#### Experimental Task and Procedure

**Emotional Semantics-Prosody Stroop-Like Task**

Participants had to listen to words with a positive or a negative emotional meaning that were pronounced with either an angry or a joyful prosody. This procedure yielded a pair of items for each word, which was either incongruent (i.e., conflict between the emotional semantic and vocal valences) or congruent (i.e., the emotional semantic valence and the vocal emotion were either both positive or both negative). The procedure of stimuli creation and details about the paradigm are fully described elsewhere (Roux et al., 2010). Congruent and incongruent items were matched according to their duration.

Two blocks of items (A and B) were constructed: each block included 80 incongruent and 80 congruent items so that the incongruent and congruent versions of a given word appeared in different blocks. Half the individuals underwent block A, the other half block B. Within each block, trials presentation order was pseudorandomized: no more

<table>
<thead>
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<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>Age (years)</td>
<td>28.7 ± 10.0</td>
<td>26.6 ± 4.8</td>
</tr>
<tr>
<td>Educational level (years)</td>
<td>15.7 ± 1.9</td>
<td>16.2 ± 2.1</td>
</tr>
<tr>
<td>RSAS score</td>
<td>5.0 ± 3.1</td>
<td>6.9 ± 3.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistical comparison</th>
<th>t</th>
<th>p</th>
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<td>Age</td>
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</tr>
<tr>
<td>Educational level</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>RSAS score</td>
<td>0.13</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Demographic and clinical characteristics of female and male participants, with statistical p-values of the comparisons of the groups (t-tests)
than three consecutive items with the same vocal emotion, congruency status, or emotional meaning were allowed.

Each trial began with the visual presentation of the two response labels (“positive” and “negative”) during 500 ms, then the emotional words were pronounced while the response labels remained on screen. Participants were instructed to judge the emotional valence of the meaning of the word while ignoring the emotional intonation of the voice with which it was pronounced. Speed and accuracy were emphasized in the instructions. Response times were measured from the onset of each word and participants could answer before the end of the word. Participants answered by pressing one of two keyboard buttons with the index and middle fingers of the right hand. The auditory stimuli were presented through speakers in a quiet room. Before the experiment began, participants received eight practice trials. During practice, the computer provided online feedback as to the correctness and speed of the responses.

Social Anhedonia Measurement

Social Anhedonia was assessed with the validated French version (Assouly-Besse, Dollfus, & Petit, 1995) of Chapman’s Revised Social Anhedonia Scale (RSAS; Eckblad, Chapman, Chapman, & Mishlove, 1982). This 40-item true/false self-report trait questionnaire measures individual differences in the experience of pleasure from social-interpersonal sources. Its internal consistency reliability is very good, with α coefficients typically exceeding 0.80, in both patients and nonclinical samples (Horan, Kring, & Blanchard, 2006).

Electrophysiological Recording

The EEG was recorded from 32 active electrodes (EasyCap, Brain Products GmbH, Gilching, Germany) according to the international 10–20 system. The setup included bilateral fronto-polar (Fp1/Fp2), frontal (F7/F8, F3/F4), fronto-central (FC5/FC6, FC1/FC2), central (C3/C4), temporal (T7/T8), centro-parietal (CP5/CP6, CP1/CP2), temporo-parietal (TP9/TP10), parietal (P7/P8, P3/P4), parieto-occipital (PO9/PO10), occipital (O1/O2), and midline (Fz, Cz, Pz, Oz) electrodes. The reference was located at the vertex (between the Fz and Cz electrodes) and a ground electrode was located in front of the Fz electrode along the midline sites. Eye blinks were detected using the fronto-polar electrodes (Fp1/Fp2). Impedance for all electrodes was kept below 10 kΩ. The EEG was recorded continuously during each session and sampled at a rate of 1,000 Hz.

The raw EEG signal was filtered off-line with a 0.4–35 Hz band-pass. Blinks were detected, then corrected using the Independent Component Analysis (ICA) method implemented in BrainAnalyzer software (Brain Products GmbH). The remaining artifacts were removed from the signal with a semiautomatic procedure when differences between maximal and minimal voltage were superior to 100 μV in 100 ms intervals, when the absolute difference between two neighboring sampling points was superior to 30 μV/ms and when the electrical activity in 100 ms intervals was below 0.5 μV. In these two last cases, segments beginning 200 ms before the event and lasting 200 ms after the event were excluded. For the ERPs extraction, EEG signals were time-locked to the beginning of the auditory presentation of the words, defining the time origin, and a 200 ms prestimulus baseline was used. Twelve hundred milliseconds EEG segments were averaged for each individual and condition (four conditions according to the emotional valence of voice and meaning: negative prosody/ negative meaning, positive prosody/positive meaning, positive prosody/negative meaning, negative prosody/positive meaning). Incorrectly answered trials were included in the analysis.

Data Analysis

Behavioral Data Analysis

We conducted repeated-measures ANOVAs on reaction time and accuracy with participants as a random factor, with one within-subject factor, Congruency (congruent versus incongruent) and one between-subject factor, Gender. In addition, we computed an emotional semantics-prosody Stroop-like score on reaction time and error rate for each participant (mean reaction time/error rates for incongruent items minus mean reaction time/error rate for congruent items). A correlation coefficient (Spearman’s) was computed between emotional semantics-prosody Stroop-like scores and the RSAS score.

ERP Analysis

Voltage Analysis

We used the same strategy for statistical analysis as Schirmer & Kotz (2003). Fifty ms time windows repeated-measures ANOVAs were conducted with one between-subject factor (Gender) and three within-subject factors: Congruency, Hemisphere (left and right), and Channel (14 pairs: FP1/FP2, F7/F8, F3/F4, FC5/FC6, FC1/FC2, T7/T8, C3/ C4, TP9/TP10, CP5/CP6, CP1/CP2, P7/P8, P3/P4, PO9/ PO10, O1/O2). To minimize the increased likelihood of Type 1 errors, only effects that reached significance (p < .05) in at least two consecutive time windows and went in the same direction were considered significant. A second ANOVA was performed for significant effects after grouping significant consecutive time windows into a larger one. Results were corrected for sphericity using the Greenhouse-Geisser method where appropriate (p-value notated as p[GG]). p-Values of post hoc single comparisons were corrected using a Holmes-Bonferroni procedure (notated as p[HB]).
Relations Between Social Anhedonia and ERP Amplitude

To investigate the influence of social anhedonia on brain electrical activity, we ran a correlation analysis between ERP voltages and RSAS scores. We first selected the ERP components whose amplitude was significantly modulated by Congruency in the former voltage analysis. ERP scores were obtained by subtracting ERP amplitudes in the congruent condition from the incongruent condition. We then computed correlation coefficients (Spearman’s) between ERP Stroop-like scores obtained from each 14 couples of electrodes and the RSAS score and tested each coefficient with a correction for multiple comparisons (Holmes-Bonferroni).

Results

Group Characteristics

Results are presented in Table 1. No one among the 34 study subjects had a psychiatric disorder according to the axis I of DSM IV-R or psychotropic treatment and the mean score of RSAS was smaller than the one usually found in larger nonclinical samples (Blanchard et al., 2011; Chapman et al., 1976; Miettunen et al., 2010).

Behavioral Results

The results are displayed in Figure 1. Reaction times could not be obtained for two participants due to technical reasons. There was a significant main effect of Congruency on error rates, $F(1, 32) = 8, p = .008$, which did not interact with Gender, $F(1, 32) = 0.7, p = .41$. More errors were made on incongruent items than on congruent ones.

There was also a significant main effect of Congruency on reaction time, $F(1, 30) = 8.8, p = .006$, which did not interact with Gender, $F(1, 30) = 1, p = .32$. Reaction times were longer for incongruent items than for congruent ones.

There was no significant correlation between the RSAS score and the emotional semantic-prosody Stroop-like score deduced from reaction time ($\rho = 0, \rho = 1$) and error rate ($\rho = .18, \rho = .307$).

Electrophysiological Results

Voltage Analysis

The first series of ANOVAs revealed a significant main effect of Congruency for the 200–250 ms, $F(1, 32) = 9, p = .005$, and 250–300 ms time windows, $F(1, 32) = 5.4, p = .027$ with a smaller amplitude for incongruent items than for congruent ones for both windows. There were significant interactions between Congruency and Channel for the 200–250 ms, $F(13, 416) = 6.8, p[GG] < 10^{-3}$ and 250–300 ms time windows, $F(13, 416) = 3.5, p[GG] = .021$. Within these time epochs, there was no significant interaction of Congruency and Channel with Gender or Hemisphere. There were no other significant effects of Congruency on two consecutive earlier or later time windows, particularly for the N450 (350–500 ms) and Sustained Potential (500–1,000 ms) time periods. There were also no other significant interactions between Congruency and Gender, Channel, or Hemisphere.

The second ANOVA, run on the 200–300 ms time window, confirmed the main effect of Congruency, $F(1, 32) = 9.1, p = .005$, the interaction of Congruency with Channel, $F(13, 416) = 5.73, p[GG] < 10^{-3}$, and the absence of interaction of Congruency with Hemisphere, $F(1, 32) = 1.2, p = .284$, or Gender, $F(1, 32) = 0.4, p = .540$. Because the P3 amplitude decreases when error rate increases in target detection paradigms (Selimbeyoglu, Keskin-Ergen, & Demiralp, 2012; Squires, Squires, & Hillyard, 1975; Sutton,
Ruchkin, Munson, Kietzman, & Hammer, 1982), the P300 amplitude modulation by congruency demonstrated here could have been explained by the greater error rate found for incongruent trials. That’s why we ran a complementary voltage analysis on the 200–300 ms time window after the exclusion of errors and trials in which answers occurred before 300 ms or after 3,000 ms post stimulus onset: the effect of Congruency, $F(1, 32) = 6, p = .02$, and the interaction between Congruency and Channel, $F(13, 416) = 4.1, p[GG] = .006$, remained significant.

Post hoc single comparisons revealed that Congruency was significant for the following couples of electrodes: P7/P8, $F(1, 32) = 9.7, p[HB] = .046$, TP9/TP10, $F(1, 32) = 10.9, p[HB] = .032$, PO9/PO10, $F(1, 32) = 10.7, p[HB] = 0.033$. Grand average ERP for these six electrodes are presented in Figure 2 (results for the other electrodes are presented in Supplemental Figure). The topographical distribution among the 32 channels of the difference wave for congruent versus incongruent trials for 100 ms intervals between 0 and 1,000 ms post stimulus onset is presented in Figure 3.

### Influence of RSAS Score on ERP Amplitudes

Results are presented in Table 2. The only significant correlation was obtained between the RSAS score and the P300 amplitude Stroop-like score computed on TP9/TP10 electrodes ($\rho = 0.51, p[HB] = .027$). Figure 4 shows that the difference in P300 amplitudes between incongruent items and congruent ones on TP9/TP10 electrodes increased with the level of Social Anhedonia.

![Figure 2](image_url)

**Figure 2.** Grand average ERP in congruent and incongruent conditions for P7/P8, TP9/TP10, PO9/PO10 sites.
Discussion

We investigated the influence of emotional prosody on language processing by recording ERP during an emotional semantic-prosody Stroop-like task. The study sought to elucidate the temporal course of the interference between semantic and vocal emotional information during speech perception. We also examined whether social anhedonia influenced the ERP components that exhibited sensitivity to this interference.

Temporal Course of the Integration of Vocal and Verbal Emotional Information

We demonstrated a significant emotional semantic-prosody Stroop-like effect both for error rates and reaction times: participants made more errors and responded more slowly to words which presented an incongruity between emotional tone and emotional content in comparison with the congruent condition.

Congruency also modulated P300 amplitude in parieto-occipital electrodes. Former studies that used the same kind of stimuli (single words pronounced with an angry or happy prosody) had suggested that the interaction of emotional prosody and word valence modulated the N400 component (Schirmer & Kotz, 2003) or even a later component, peaking around 1,000 ms (Schirmer et al., 2006). The present result indicates that this interaction may occur earlier than previously suggested, as soon as 200 ms post stimulus onset. Because emotional prosody exerts an early influence on word processing at the brain level, this information seems to be highly salient in speech perception. We found a smaller P300 amplitude for incongruent items than for congruent ones. Such a decrease of P300 amplitude in incongruent condition has been shown in several nonemotional Stroop-like paradigms (Ilan & Polich, 1999; Shen, 2006).

Table 2. Correlation coefficients (Spearman’s $\rho$) between ERP Stroop-like scores obtained from each 14 couples of electrodes and the RSAS score.

<table>
<thead>
<tr>
<th>Electrodes</th>
<th>Spearman’s correlation coefficient $\rho$</th>
<th>Corrected $p$-value (Holmes-Bonferroni)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fp1–Fp2</td>
<td>-0.03</td>
<td>0.834</td>
</tr>
<tr>
<td>F7–F8</td>
<td>0.08</td>
<td>1.000</td>
</tr>
<tr>
<td>F3–F4</td>
<td>0.36</td>
<td>0.488</td>
</tr>
<tr>
<td>FC5–FC6</td>
<td>0.25</td>
<td>1.000</td>
</tr>
<tr>
<td>FC1–FC2</td>
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<td>T7–T8</td>
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<td>C3–C4</td>
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<td>1.000</td>
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<td>TP9–TP10</td>
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<td>0.027</td>
</tr>
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</table>

Figure 3. Topographical distribution among the 32 channels of the difference wave for congruent versus incongruent trials for 100 ms intervals between 0 and 1,000 ms post stimulus onset.
2006; Szucs et al., 2009) but the present study is the first one, to our knowledge, to extend this finding to an emotional semantic-prosody Stroop-like paradigm. This decreased P300 amplitude for incongruent items could not be explained by the greater error rate found in this condition because the effect remained significant even when errors were excluded from the voltage analysis. P300 amplitude reflects activation of neural assemblies associated with event categorization (Shen, 2006), in our case, an emotional valence categorization. Because some of these neural assemblies might be common for the categorization of emotional prosody and emotional meaning, a greater neural activity would be measured when both sources have the same valence than when they have opposite valence. In incongruent items, neural activations may counteract each other, leading to decreased P300 amplitude.

We did not find any modulation of amplitude by congruency for later ERP components such as N400 or Sustained Potential, suggesting that influence of emotional prosody on verbal processing occurred earlier than previously suggested (Schirmer & Kotz, 2003; Schirmer et al., 2006). This discrepancy might suggest a language-specific effect on emotional semantic-prosody Stroop-like paradigms. It has been suggested that different languages might be differentially attuned to vocal emotion according to cultural variation in emotional processing (Ishii, Reyes, & Kitayama, 2003; Kitayama & Ishii, 2002). In languages that are highly attuned to emotional prosody, neural signature of the influence of emotional prosody on verbal processing might occur earlier than in languages less attuned to emotional prosody. Further studies should record ERP during emotional semantic-prosody Stroop-like paradigms in various languages.

**Interindividual Differences: Influence of Social Anhedonia and Gender**

We found a significant link between the social anhedonia score and the modulation of the P300 amplitude by the congruency between the emotional meaning of a word and the emotional valence of the voice: the influence of emotional prosody on the P300 amplitude increased with the level of social anhedonia. To our knowledge, this is the first study to show a link between electrical brain activity during emotional processing and social anhedonia. An association between social anhedonia and the emotional semantic-prosody Stroop-like effect has been demonstrated in a group of schizophrenic patients, but at the behavioral level (Roux et al., 2010): the emotional semantic-prosody Stroop-like score deduced from RT increased with social anhedonia. In the present study, this association was absent at the behavioral level, but present at the ERP level. The lack of replication of this association for RT might be explained by the lower variability of emotional semantic-prosody Stroop-like found in the present study (SD = 56.6 ms) compared to the previous one (SD = 76.5 ms), which is not surprising as performances of individuals with schizophrenia are usually more variable than controls’ performances.

The increase of P300 amplitude with the level of social anhedonia is compatible with the general hypothesis that social anhedonia does not correlate with a decreased perception of emotional information, but rather with an intact perception of these information, coupled with a decreased ability to inhibit emotional information. A deficit in the executive control of emotional prosodic information may lead to an oversensitivity to vocal emotions in subjects having high levels of social anhedonia. According to Meehl, social anhedonia, which is a core symptom of schizophrenia, is not a consequence of a general decrease in hedonic capacities but can be explained by an “interpersonal aversiveness” (Meehl, 1962, 2001). We suggest that the decrease in the cognitive control of emotional cues such as prosody is a psychological mechanism leading to increased aversive experiences occurring in social contexts among individuals with higher self-reported social anhedonia. P300 modulation could be a candidate cerebral marker of this defect in the executive control on emotional prosody.

While some other studies had observed that sensitivity to emotional prosody was larger in females than males (Schirmer & Kotz, 2003; Schirmer, Kotz, & Friederici, 2002, 2005; Schirmer et al., 2006), we did not observe any effect of gender. In the present study, women weren’t more attuned to vocal emotion than men, either at the behavioral level, or at the ERP level (note that no differ-
ences in age or educational level were observed between men and women). The reason could be that gender influences are associated with specific components such as the N400 that was not found modulated by congruency in the present study (Schirrmer & Kotz, 2003).

Limitations

Before reporting the limitations of the study, we first discuss the term used to describe the emotional semantic-prosody compatibility effect. The “Stroop-like” designation was used in its broad acception and did not suggest that the emotional semantic-prosody congruency effect demonstrated in this study was determined by the same cognitive mechanisms as the original Stroop color-naming paradigm. Actually, most theoretical accounts of the Stroop color-naming effect place the interference at the response selection stage but not at the stimulus evaluation stage because no congruency effects on the P300 could have been demonstrated in the classical Stroop task (Duncan-Johnson & Kopell, 1981; Ilan & Polich, 1999). In contrast, our results suggest that the emotional semantics-prosody congruency effect affected the P300, thus suggesting the interaction between prosody and semantics occurred earlier than the interaction between word reading and color naming.

The first limitation is the lack of a control condition with neutral prosody which has prevented us from exploring valence-specific effects of the influence of emotional prosody on verbal processing. This is particularly important considering social anhedonia which is by definition a defect in the experience of positive emotion. The lack of neutral condition also prevented us from disentangling interference from facilitation effects of emotional prosody on word processing.

The participants we have recruited were less socially anhedonic than the general population. This was explained by the fact they were predominantly college students, who are usually less anhedonic than less educated individuals (Miettunen et al., 2010). Further studies should confirm the link between P300 amplitude modulation and social anhedonia on a wider range of social anhedonia scores. It may be necessary to compare the P300 amplitude modulation in two groups of participants matched on several socio-demographic characteristics (age, gender, educational level, and IQ) with low versus high level of social anhedonia. In the same line, a deficit in executive functions measured by the Wisconsin Card Sorting Test has been demonstrated in individual with high level of social anhedonia (Tallent & Kerns, 2006; Martin & Kerns, 2010). We still do not know whether the link between social anhedonia and the P300 amplitude modulation, which indexes the executive control of emotional prosody, is specific to emotion or whether it could be explained by a general deficit in executive functions in social anhedonia.

Conclusion

In summary, we have shown that, in French, vocal emotional information was salient enough to interfere early with verbal processing, as soon as 200 ms after the beginning of the word and during the stimulus evaluation process. When emotional prosody was incongruent with the emotional meaning of a word, P300 was decreased in amplitude. This modulation in P300 amplitude increased with the individual’s level of social anhedonia, suggesting that emotional prosody may be particularly salient and difficult to modulate for socially anhedonic persons.

Acknowledgments

We thank Marwa El Zein for her help in collecting data. We also thank Franck Ramus and Nadine Bazin for their helpful suggestions.

References


**Accepted for publication:** August 20, 2013  
**Published online:** January 15, 2014