Definition of emotion

Decoding others' emotional mental states through voice
Emotional processes

"Emotions are – episodes of massive, synchronized recruitment of mental and somatic resources allowing to adapt to or cope with a stimulus event subjectively appraised as being highly pertinent to the needs, goals, and values of the individuals".

In this definition the notion of synchronization is a central feature. Emotions are seen as occurring when the cognitive, physiological and motor/expressive components – which are usually more or less dissociated in serving separate functions – synchronize, as a consequence of a situation/event appraised as highly relevant for an individual.

Scherer, 2001, 2004
Grandjean, Sander, & Scherer, Consciousness and Cognition, 2008

The five components of emotion

Integrator (reflexive and appraisals of other component states)
Subjective feeling (appraisals and perceptions)
Behavioral organization (selection of needs and goals, action tendencies)
Motivation (biological needs / pulsions, intentional goals / objectives)

SNC (cortical et sous cortical)

Elaboration of information (appraisal of stimulus and situation)
Cognition (automatic / non-automatic appraisals, implicit / explicit)
Support (regulation, homeostasis and energy for urgency for ex.)
Peripherical processes (neuro-endocrinal)
Motor sub-system (execution of action, communication of reaction and intention)
Expressions and behaviours (facial movements, vocal, bodily gestures)

SNS (striated muscles)

CNS (cortical and sub-cortical)
emotional prosody

Ability of non-human animals and humans to infer the emotional states of others and then adapt their behaviors correspondingly.

Crucial for survival and social adaptation and cooperation.


emotional prosody

all vocalization modifications related to vocal tractus changes during an emotional episode.

supra-segmental (e.g. pitch) and segmental modifications (e.g. formants).


emotional prosody

The ability to infer the others’ emotional mental states on auditory modality requires a set of sensory equipments and neuronal networks able to construct:

i. Basic dynamic auditory percepts
ii. Dynamic auditory objects
iii. Implicit and/or explicit attributions of emotional characteristics.
Main questions addressed:

- How our CNS is able to build up an auditory emotional object?

- What are the subprocesses involved and which brain areas contribute to the decoding? How the neuronal network(s) is(are) organized?

- How the individual’s attentional focus modulates the activity/functional structure of this(ese) neuronal network(s)?

(See Scherer, 2001; Grandjean et al., 2009; Sander et al., 2003)
Auditory stimulus

**Distal indicators (objective measures)**
- Fundamental (mean, variance F0)
- Quantification of energy in time (envelope)
- Quantification of energy in different frequency bands
- Temporal dynamic of F0

**Proximal percepts (subjective judgments)**
- Intonation or pitch
- Intensity
- Voice quality
- Pitch unfolding

**Emotional attributions**
- Joy
- Fear
- Anger

---


toward an integrative model of emotional prosody decoding

Emotional prosody perception and spatial attention
Two experiments: sparse fMRI acquisition (N=15)

Main experiment: attention to the left or the right ear was blocked, gender decision task

Control experiment: comparison task between two successive sounds

Contrast: Anger vs Neutral Middle Superior Temporal Sulcus response to anger prosody
Activation occurred in previously reported voice-sensitive areas (Belin et al., 2000)

Bilateral STS; \( P < .001 \), uncorrected

amygdala

right amygdala
RFX, P < .005, uncorrected

Fruehholz & Grandjean (in press). Cortex

OFC

orbitofrontal cortex
RFX, P < .001, uncorrected
P < 0.05 corrected at the cluster-level

Inter-individual differences

The activity an OFC region is highly correlated with BIS-BAS when Anger stimuli are in the focus of attention (participant’s task = gender decision)

Correlation between activity in OFC and subjective ratings of Behavioral Inhibition System (BIS of Gray's BIS-BAS model, 1982; Carver & White, 1994)

![Graph showing correlation](image)

\[ r = 0.87, P < 0.001 \]

auditory extinction – neglect patients

six patients with auditory extinction (strokes in the right parietal regions).

dichotic listening (pseudo-words, Banse & Scherer), duration: 4 seconds. Angry, Happy, Fearful and Neutral prosody (matched for the mean of energy).

Grandjean et al., Neuropsychologia, 2008
auditory extinction

Anova repeated measures with Prosody factor (4 levels), \( F(3,15)=5.69, \ p<.009 \), all contrasts [emo-neutral] were significant at \( p<.05 \)

Grandjean et al., *Neuropsychologia*, 2008

Modulation of auditory extinction

Grandjean et al., *Neuropsychologia*, 2008
Orbito-frontal cortex, caudate nucleus (Kotz et al., 2003; Bach et al., 2008; Paulmann, Pell, & Kotz, 2008), temporo-parietal junction, and temporal cortex.


What are the subprocesses involved and which brain areas contribute?

How the individual’s attentional focus modulates the activity of the involved brain regions?
**Method: Sparse sampling**

- Frueholz, Ceravolo, & Grandjean (2012). Cerebral Cortex

**High spatial resolution**

**Scan parameters**
- 24 oblique slices, 2 mm, DF 20%
- $\Delta z = 5.8$ cm
- Inplane 1.5 * 1.5 mm voxel
- TA 1.5 s

Frueholz, Ceravolo, & Grandjean (in press). Cerebral Cortex
Two tasks: prosody and gender discrimination, pseudo-words: molen, belam, nikalibam, and kudsemina.

Voice localizer: vocal > non-vocal
Voice localizer: vocal > non-vocal – inflated brain

Belin, et al., 2000

Fruehholz, Ceravolo, & Grandjean (2012). Specific brain networks during explicit and implicit decoding of emotional prosody. Cerebral Cortex

emotional prosody
contrast Anger vs Neutral

superior temporal gyrus and sulcus/inferior frontal gyrus and fronto-operculum

Fruehholz, Ceravolo, & Grandjean (2012). Specific brain networks during explicit and implicit decoding of emotional prosody. Cerebral Cortex
emotional prosody  Task: explicit discrimination of emotional prosody

emotional prosody  Task: gender discrimination (implicit decoding of emotional prosody)
emotional prosody

Independencies of F0/Intensity means and variations for the two tasks

Frueholz, Ceravolo, & Grandjean (2012). Cerebral Cortex

emotional prosody

Dependencies of F0 mean and variations and emotional explicit tasks

Frueholz, Ceravolo, & Grandjean (2012). Cerebral Cortex
How the neuronal network(s) is(are) organized?

Psychophysiological interactions analysis - PPI
Psychophysiological interactions analysis - PPI  p-STG as seed region

Explicit

Implicit


Psychophysiological interactions analysis – PPI  bilateral IFG as seed region

Explicit

Implicit

Psychophysiological interactions analysis – PPI

Summary


Delineation of the amygdala for each participant

Amunts et al., 2005; Eickhoff et al., 2005

Fruehholz & Grandjean (2013). Different amygdala subregions process and rapidly adapt to threatening voices. Cortex.

Modulation of activity in subregions of Amygdala: Anger versus Neutral

Fruehholz & Grandjean (in press). Different amygdala subregions process and rapidly adapt to threatening voices. Cortex.
Amygdala and habituation – sensitization - desensitization

Amygdala and habituation – sensitization - desensitization
The Amygdala - Orbito-frontal coupling

Intracranial recordings

local field potentials  
depth electrodes of interest

Orbitofrontal cortex

Amygdala

Right OFC  Left OFC

Right A  Left A  Right A
Presentation of binaural sounds using headphones (750ms)

30 trials of each emotional type (angry, happiness, sadness, fearful, neutral) in three blocks, presented in pseudo-randomly order.

Control condition: extracted envelope of the sounds + white noise/mean F0 (static)/F0 dynamic (changes of F0 in function of the time)

Grandjean, et al., in preparation

Local field potentials

sound 1
750 ms of duration
Silence duration between 1500 to 2000ms

sound 2
Silence duration between 1500 to 2000ms

Participant's response (motor) only when the last sound is identical to the previous stimuli (10% of the stimuli), these trials were excluded of further analyses.

Ifps analysis

Wavelet analyses of each trial

Averaged map of differences (e.g. differences anger vs neutral)

Statistical map at \( P < .05 \)

Permutation tests on time-frequency space
Hertz

significance at p<.05 (permutation with 1000 iterations)

Ifp results
electrode in the left amygdala: anger/neutral

left amygdala responses to emotional prosody

Ifp results

anger vs neutral

fear vs neutral
test of the LFPs of the left medial OFC

more medial contact

bilateral test
P<.025

neuronal synchronization

neuronal synchronizations and neural networks

measure of the oscillatory phase synchrony as an indicator of functional coupling between distant brain regions (Lachaux et al., 1999).

based on animal studies using microelectrodes local binding between neuronal responses have already been demonstrated (e.g. Singer & Gray, 1995; Neuenschwander et al, 1995).

neuronal synchronization
neuronal oscillations and synchronization of distant neural networks

model "Communication Through Coherence" (CTC, Fries, 2005, TICS)

Spike arriving at peak excitability
- Spike missing peak excitability

neuronal synchronization
neuronal oscillations and synchronization of distant neural networks

local synchronisation (mm) at high frequencies (i.e. Gamma)
distant synchronisation (cm) at low frequencies (i.e. Theta)

Guderian & Duzel 2005, Hippocampus; Canolty et al., 2006, Science; Fries et al., 2007, Science; Canolty & Knight, 2010, TICS.
measures of the phase synchrony of oscillations of distant brain regions

in the following analyses we used a complex Gabor wavelet (+-2Hz) to compute the phase locking value (PLV), it was computed at each frequency from 5 Hz to 40 Hz.
measures of the phase synchrony of brain oscillations

neuronal synchronization

PLS between left amygdala and left medial OFC during angry prosody exposure
Neutral prosody

Anger prosody

Neuronal synchronization

synchrony between left medial OFC and left amygdala: comparison between anger vs neutral prosody

Group analysis (N=5)

neuronal synchronization

Comparison between intra-hemispheric and inter-hemispheric emotional modulated coupling between amygdala and OFC neuronal activity.

Neural prosody

Anger prosody

decreasing of coupling on the medial-lateral axis of OFC

Neural synchronization

Anger
connectivity between amygdala and the medial OFC in monkeys (Ghashghaei, et al., 2007, *NeuroImage*)

neuronal synchronization

relations amygdala - OFC

neutral vs Control stimuli Unvoiced Envelope
neuronal synchronization

neuronal coupling: phase shift or not?

Neuronal synchronization AND zero-lag phase

Neuronal desynchronization
Orbitofrontal cortex and dynamic filtering of emotions. Cognitive, Affective, and Behavioral Neuroscience.

emotion and spatial attention  

right medial OFC

**ERPs**

Anger Att vs Anger UnAtt (p<.025)

**CWTs**

Anger Att vs Anger UnAtt (p<.025)

emotion and spatial attention  

amygdalo-OFC neuronal synchronization for anger vs neutral

**a** Neutral

**b** Angry

**c** P-values of the difference

**d** P-value in degrees
emotion and spatial attention  amygdalo-OFC neuronal synchronization

Amygdala - medial OFC synchrony  to  Amygdala - lateral OFC synchrony

emotion and spatial attention  amygdalo-OFC neuronal synchronization

Medial OFC - Amygdala synchrony  to  medial OFC - lateral temporal lobe synchrony
Modulation of synchronization by attention

Unfolding of neuronal synchronization and attention
Amygdalo-OFC synchronization in face perception (N=4)

Behavioral effects of Amygdalo-OFC synchronization in face perception

Interaction effect on the RT with Emotion and Phase-lag indice (p<.001).
Conclusions

Convergence of experimental evidences for the involvement of a complex network including STS-STG, IFG, amygdala, OFC in decoding emotional prosody.

The fronto-temporal network is complex and organized in several sub-regions

Implicit task: pSTG regions, the bilateral IFG, and bilateral basal ganglia.
Explicit: mSTG regions, the left IFG, amygdala, left basal ganglia, and sgACC.

The IFG, planum polare, and a specific part of the mSTG are not sensitive to basic acoustical features (F0 and intensity) while a large part of the pSTG is sensitive to them.

Early neuronal modulations within amygdalae when emotion is unattended.

Medial OFC modulations are stronger when the emotional prosody is attended compared to unattended.

Increase of neuronal synchronization in thêta and alpha bands between amygdala and medial OFC for anger prosody modulated by attentional processing.