Affective Sciences
SWISS NATIONAL CENTER OF COMPETENCE IN RESEARCH

NEAD
Neuroscience of Emotion and Affective Dynamics

The Synchronized Brain in Emotional Processing

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NEAD
Neuroscience of Emotion and Affective Dynamics Lab

Definition of emotion

Decoding others' emotional mental states through voice

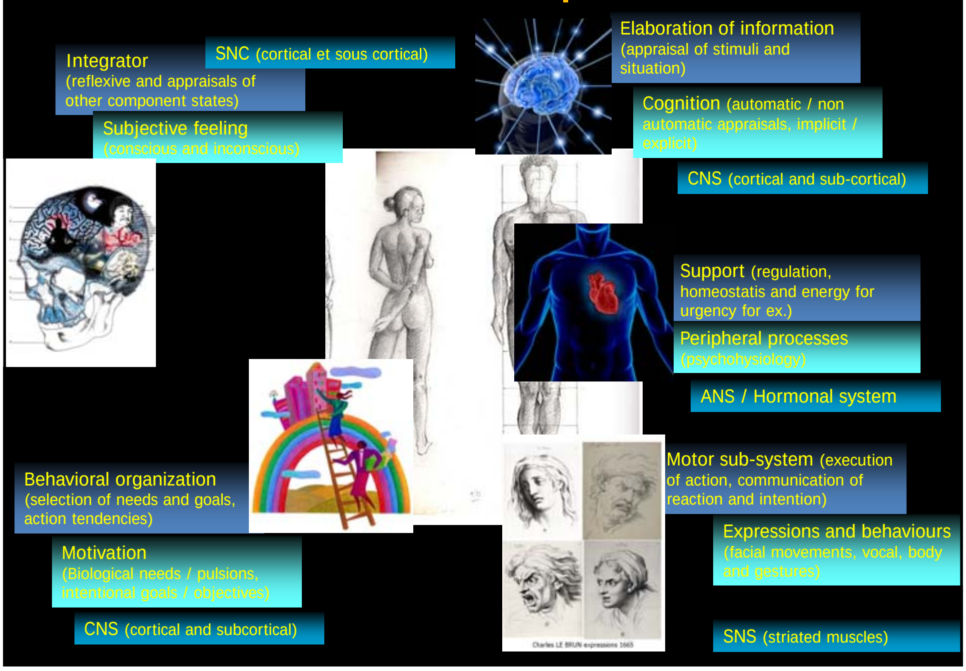
Emotional processes

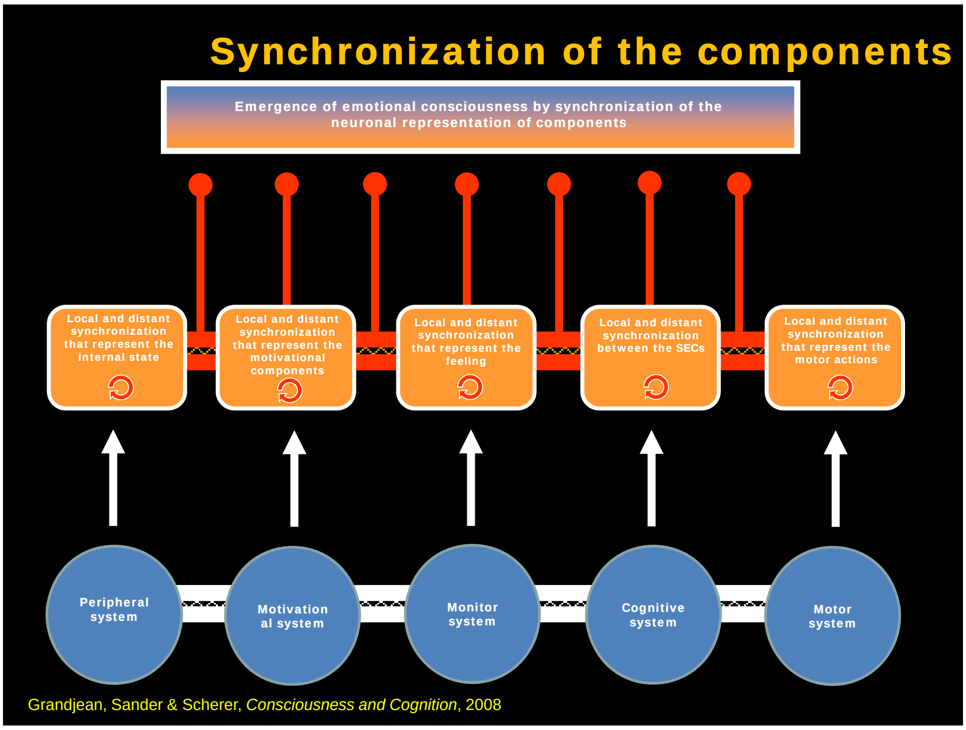
"Emotions are – episodes of massive, synchronized recruitment of mental and somatic resources allowing to adapt to or cope with a stimulus event subjectively appraised as being highly pertinent to the needs, goals, and values of the individuals".

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





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.

Chandrasekaran, Lemus, Trubanova, Gondan & Ghazanfar (2011). Monkeys and humans share a common computation for face/voice integration. *PLoS Computational Biology*.

Ghazanfar AA and Santos LR (2004) Primate brains in the wild: the sensory bases for social interactions. *Nature Reviews Neuroscience*.

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).

Grandjean, Baenziger, & Scherer (2006). *Progress in Brain Research.*

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.

emotional prosody

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)?

emotional prosody

Emotional expression

(inside or outside the focus of attention)

Perceptual processes

Attentional processes

Memory processes

Appraised

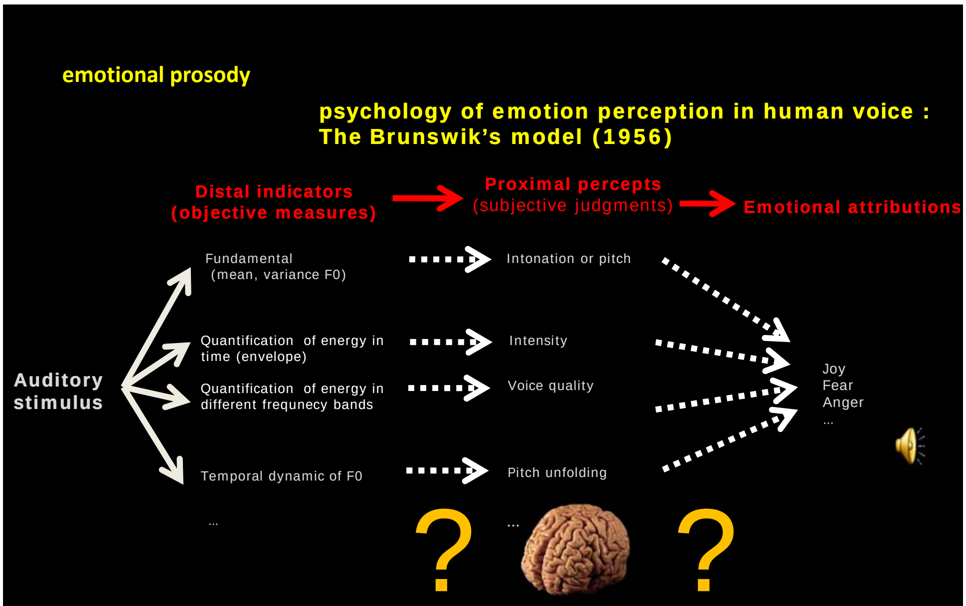
Expressions

Peripheral physiology

Action tendencies

Feeling

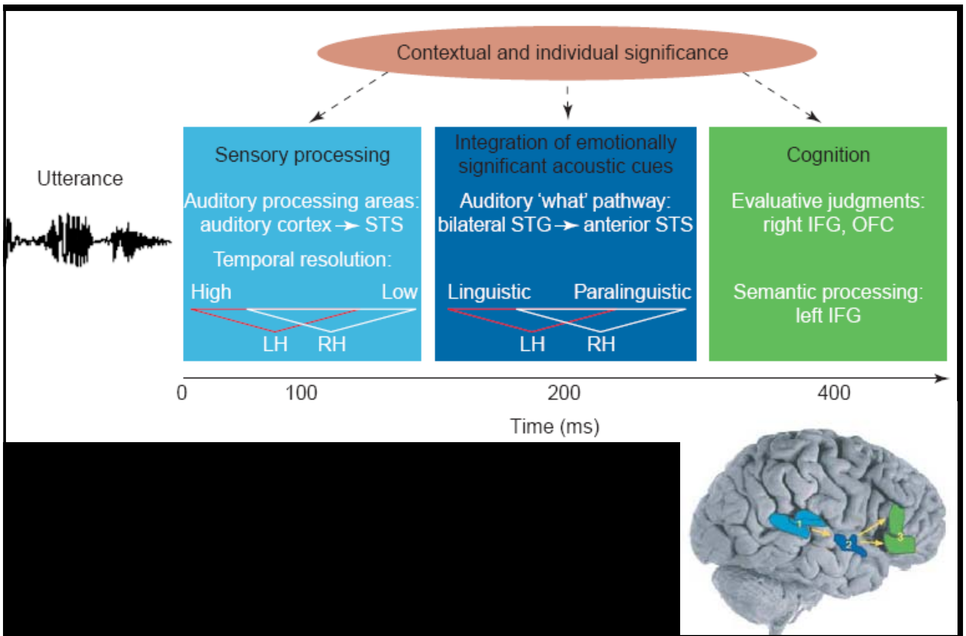
(See Scherer, 2001; Grandjean et al., 2009;Sander et al., 2003)



Grandjean, Baenziger, & Scherer (2006). Intonation as an interface between language and affect. *Progress in brain research, 156*.

Grandjean & Baenziger (2009). L'expression vocale des émotions. *Traité de psychologie des émotions*. Dunod.

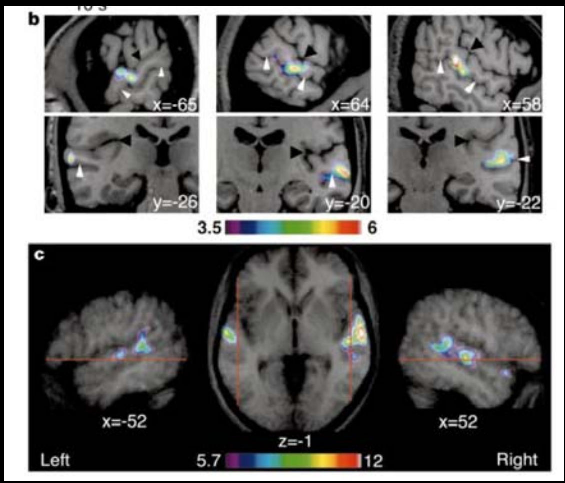
Scherer (1988). On the symbolic function of vocal affect expression. *Journal of language and social psychology, 7*.



Schirmer and Kotz (2006). Beyond the right hemisphere: : brain mechanisms mediating vocal emotional processing. *TICS*.

Schirmer, Fox, & Grandjean (2012). On the spatial organization of sound processing in the human temporal lobe: A meta-analysis. *Neuroimage*.

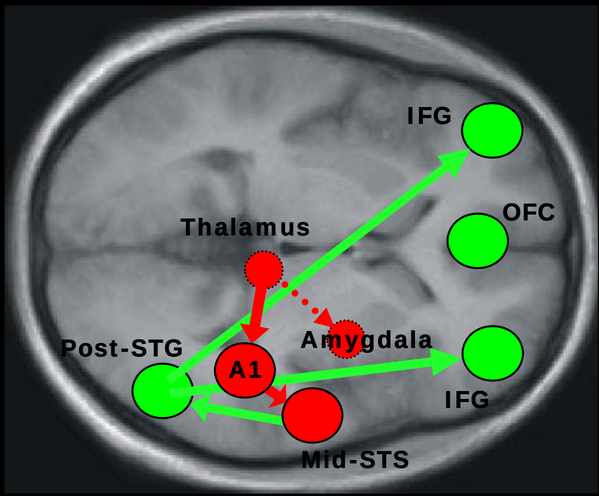
Voice temporal sensitive area (Belin, et al., 2000, 2004)



toward an integrative model of emotional prosody decoding

emotional prosody

toward an integrative model of emotional prosody decoding



Bottom-up modulation (stimulus-driven)

Top-down modulation (task-dependent)

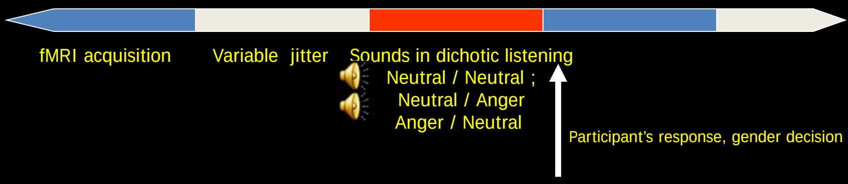
Wildgruber, Ethofer, Kreifelts, Grandjean (2008). Cerebral processing of emotional prosody: A network model based on fMRI studies. Proceedings of the International Conference of Speech Prosody.

Emotional prosody perception and spatial attention

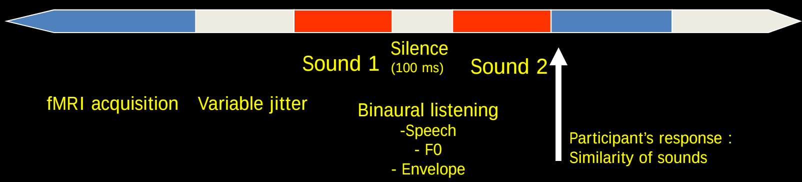
emotional prosody

Two experiments : sparse fMRI acquisition (N=15)

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

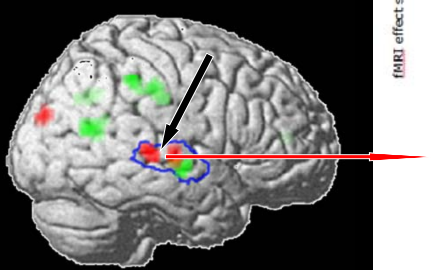


Control experiment : comparison task between two successive sounds

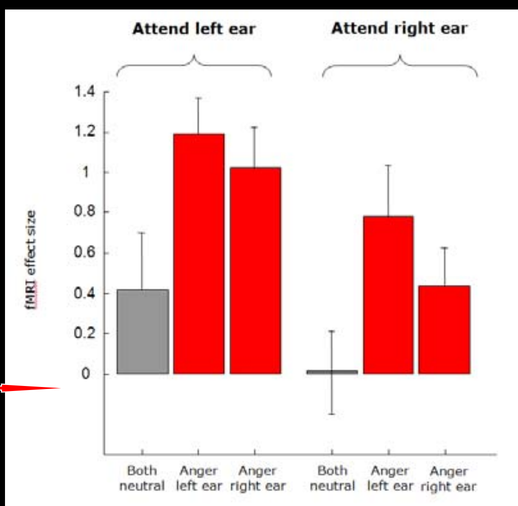


emotional prosody

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

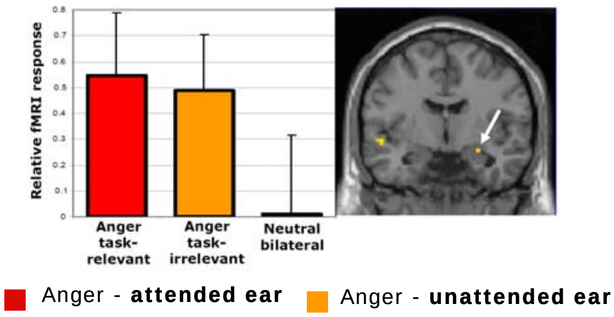


Anger (AN, NA) Neutral (NN)

Grandjean, et al. (2005). The Voices of Wrath: Brain responses to angry prosody in meaningless speech. *Nature Neuroscience.*

amygdala

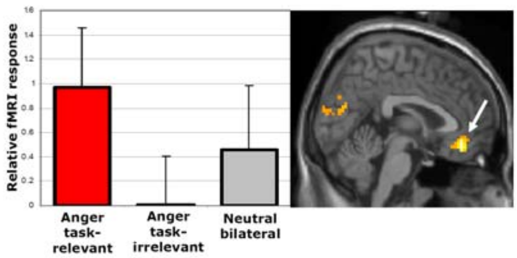
right amygdala
RFX, P <.005, uncorrected



Sander, Grandjean, Pourtois, Schwartz, Seghier, Scherer, & Vuilleumier (2005). *Neuroimage*.
Bach, Grandjean, Sander, Herdener, Strik, & Seifritz (2008). *Neuroimage*.
Fruehholz, Ceravolo, & Grandjean (2012). *Cerebral cortex*.
Fruehholz & Grandjean (in press). *Cortex*

OFC

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

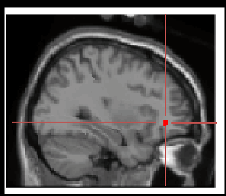


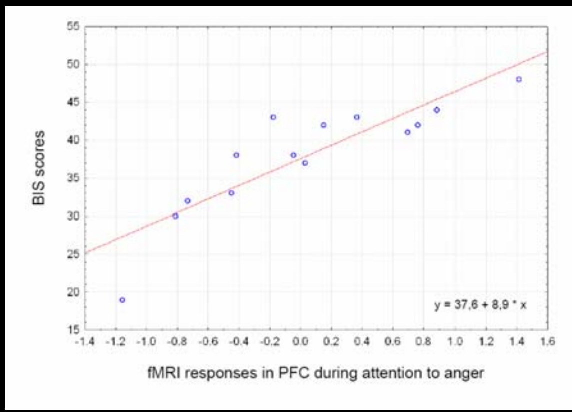
Sander, Grandjean, Pourtois, Schwartz, Seghier, Scherer, & Vuilleumier (2005). *Neuroimage*.

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)





r = 0.87, *P* < 0.001

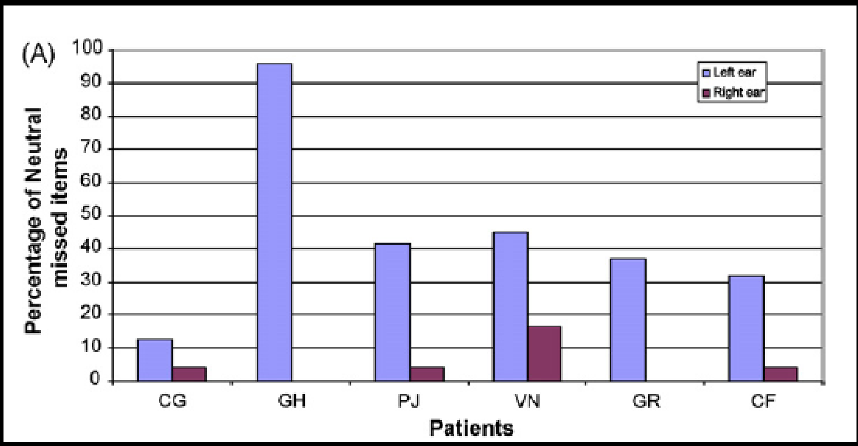
auditory extinction – neglect patients

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

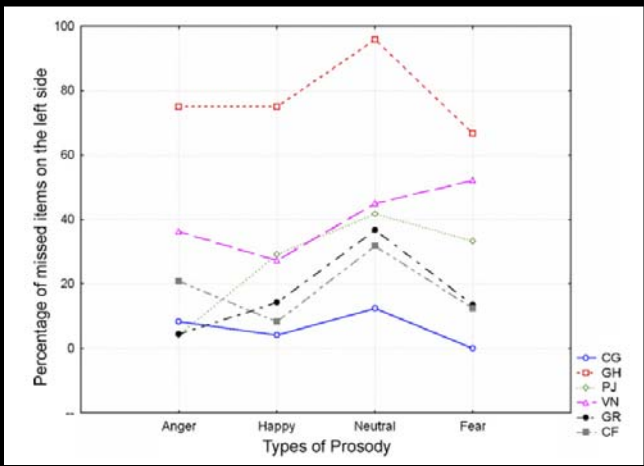
auditory extinction



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*

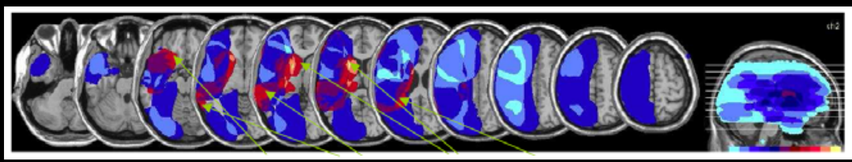
Modulation of auditory extinction

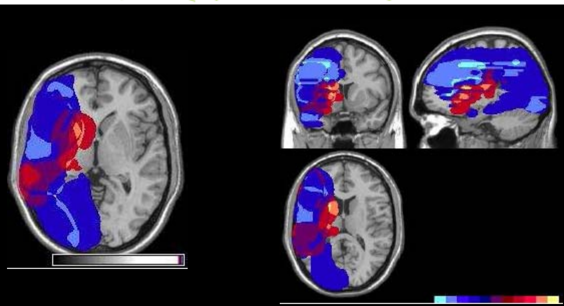


Grandjean et al., *Neuropsychologia, 2008*

emotional prosody

brain regions significantly different between two groups: high versus low-scores in the experimental condition with emotional prosody





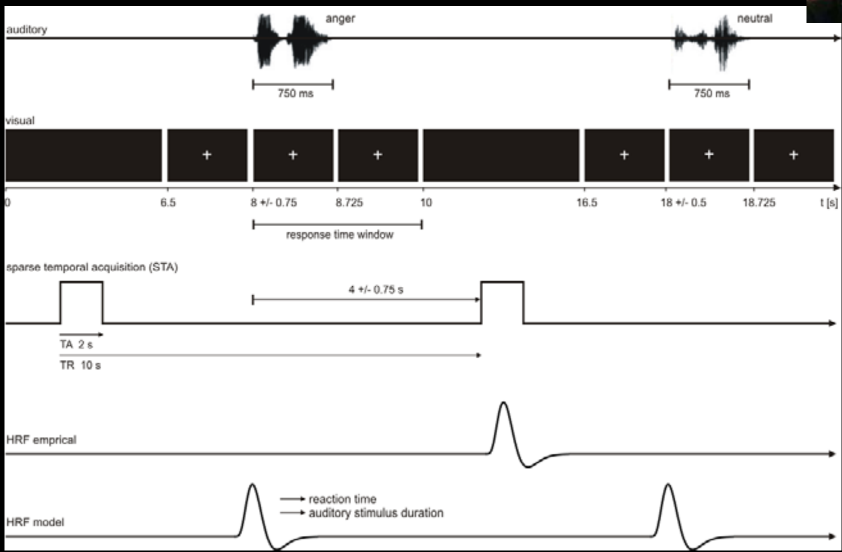
Orbito-frontal cortex, caudate nucleus (Kotz et al., 2003; Bach et al., 2008; Paulmann, Pell, & Kotz, 2008), temporo-parietal junction, and temporal cortex.

Grandjean et al. (2008). Effects of emotional prosody on auditory extinction for voices in patients with spatial neglect. *Neuropsychologia.*

What are the subprocesses involved and which brain areas contribute?

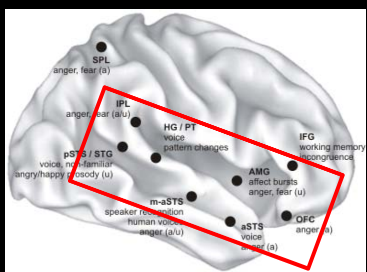
How the individual's attentional focus modulates the activity of the involved brain regions?

Method: Sparse sampling



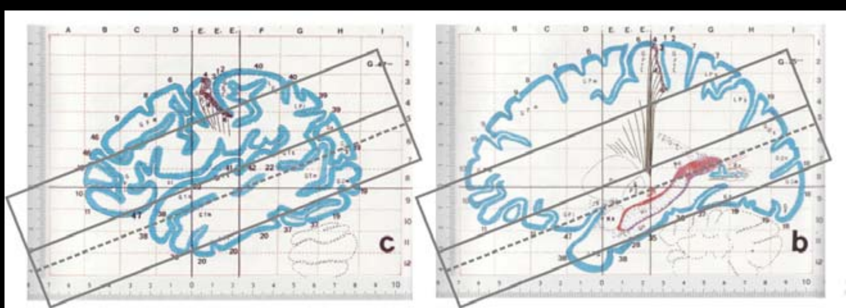
Fruehholz, Ceravolo, & Grandjean (2012). Cerebral Cortex

High spatial resolution



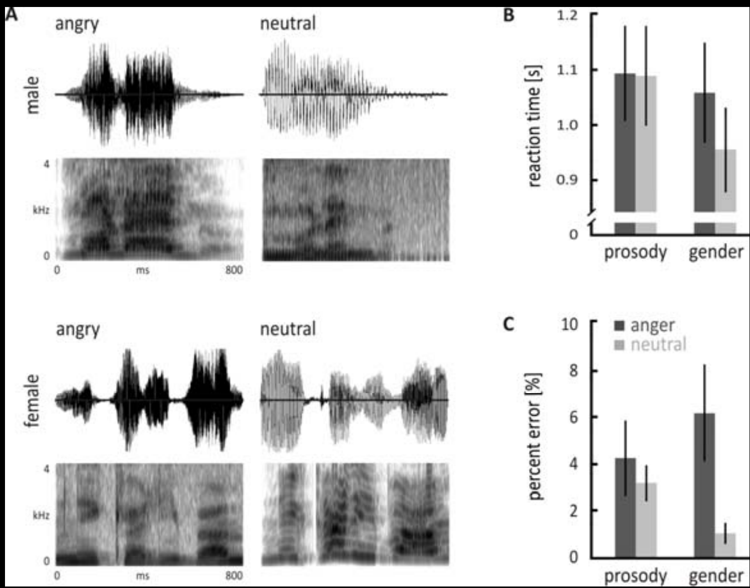
scan parameters
24 oblique slices, 2 mm, DF 20%
$\Delta z \sim 5.8$ cm

inplane 1.5 * 1.5 mm voxel
TA 1.5 s



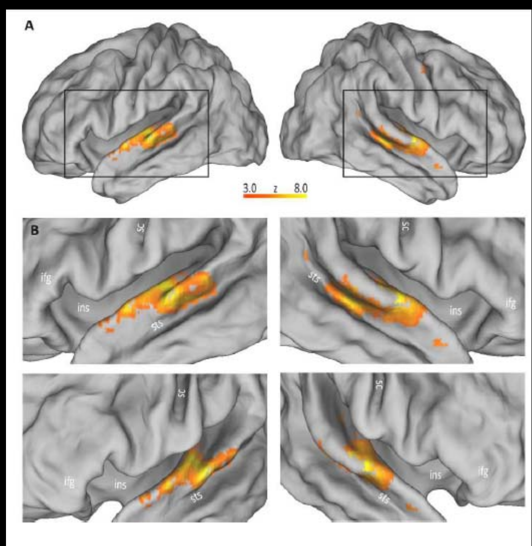
Fruehholz, Ceravolo, & Grandjean (in press). Cerebral Cortex

Two tasks: prosody and gender discrimnation ,
pseudo-words : molen, belam, nikalibam, and kudsemina



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

Voice localizer: vocal > non-vocal

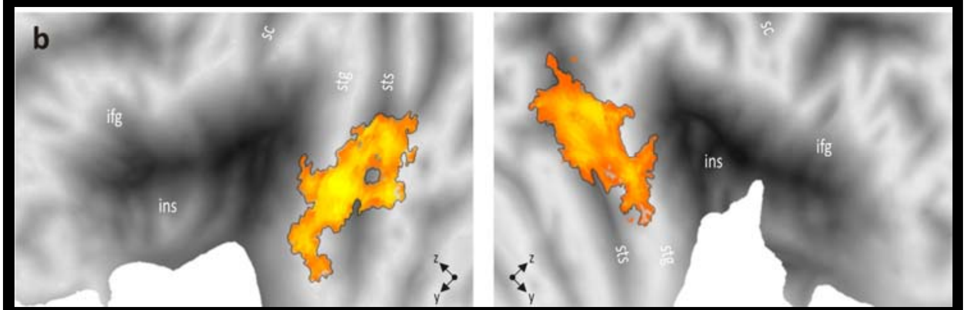


Belin, et al., 2000

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

Voice localizer: vocal > non-vocal – inflated brain

Left Right



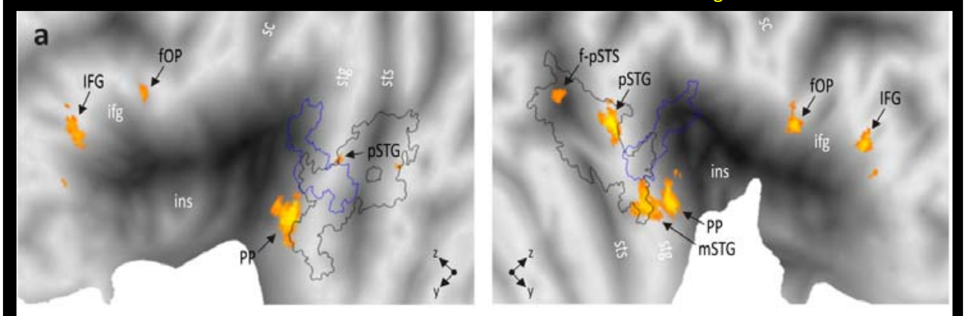
Belin, et al., 2000

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

emotional prosody

contrast Anger vs Neutral

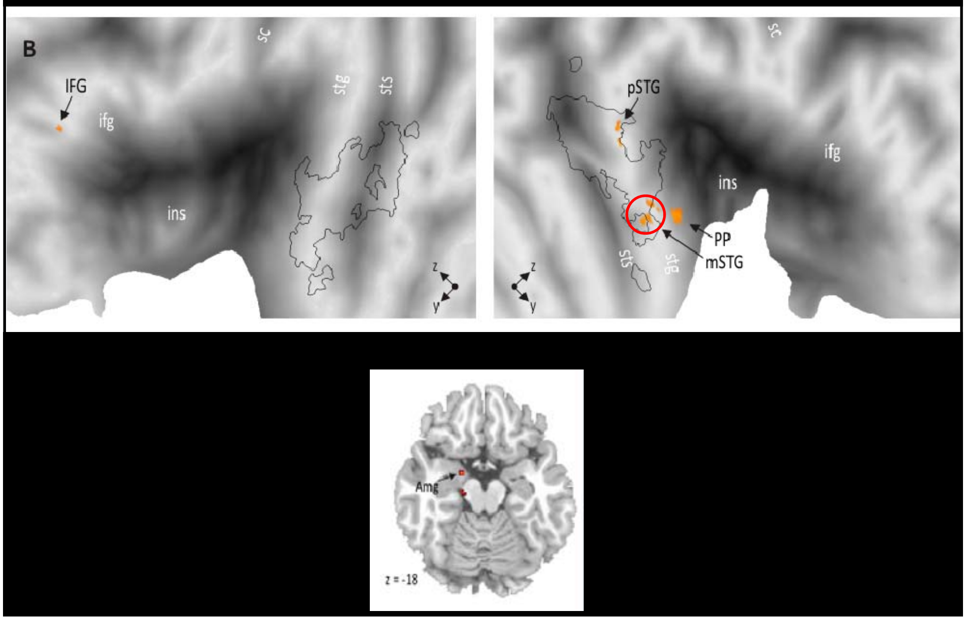
Left Right



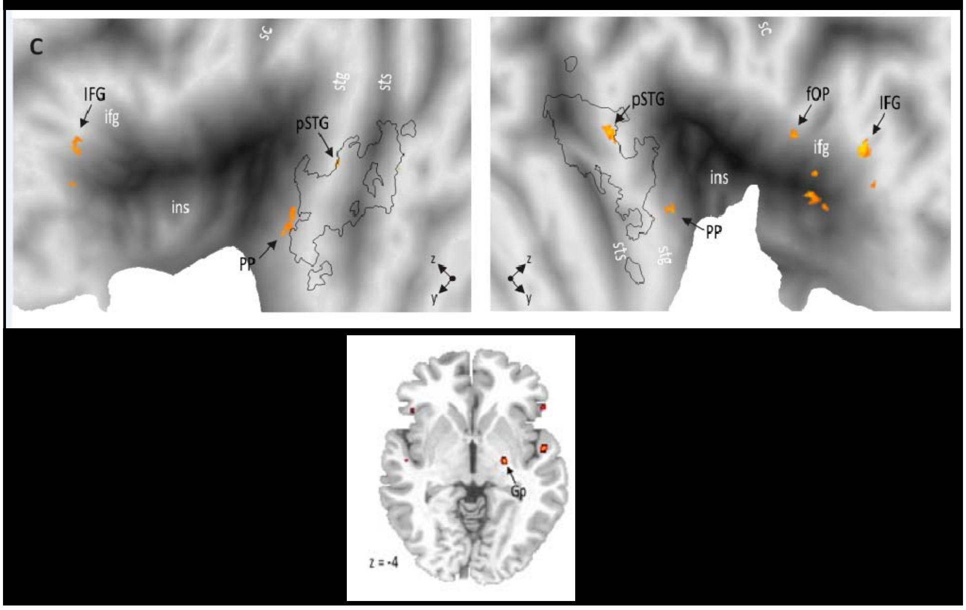
superior temporal gyrus and sulcus/inferior frontal gyrus and fronto-operculum

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

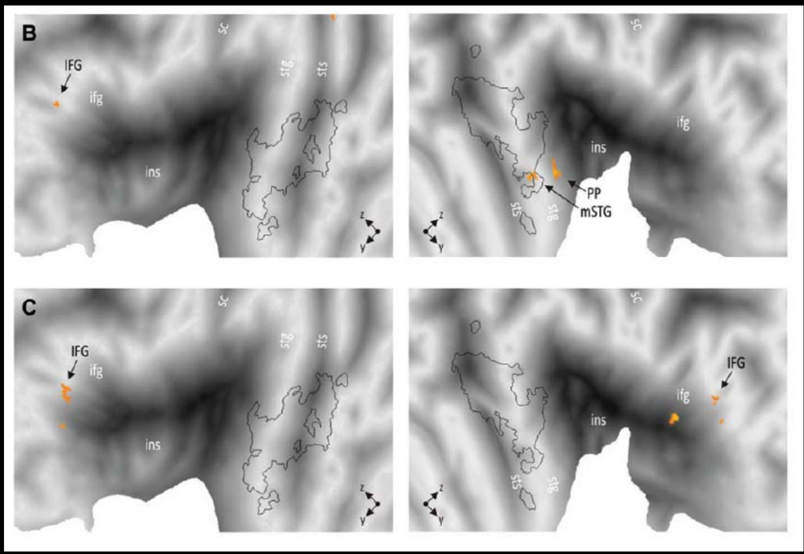


emotional prosody Task: gender discrimination (implicit decoding of emotional prosody)



emotional prosody

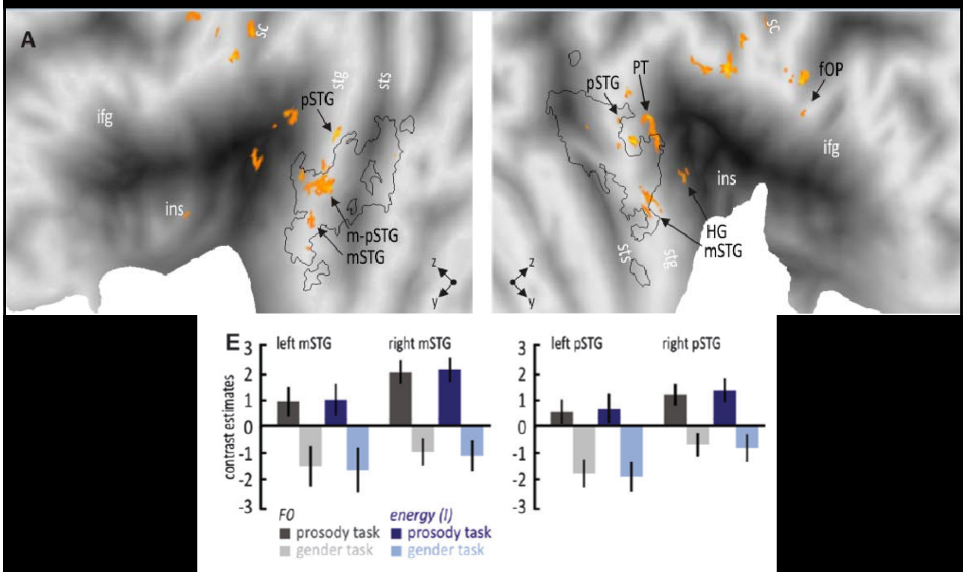
Independencies of F0/Intensity means and variations for the two tasks



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

emotional prosody

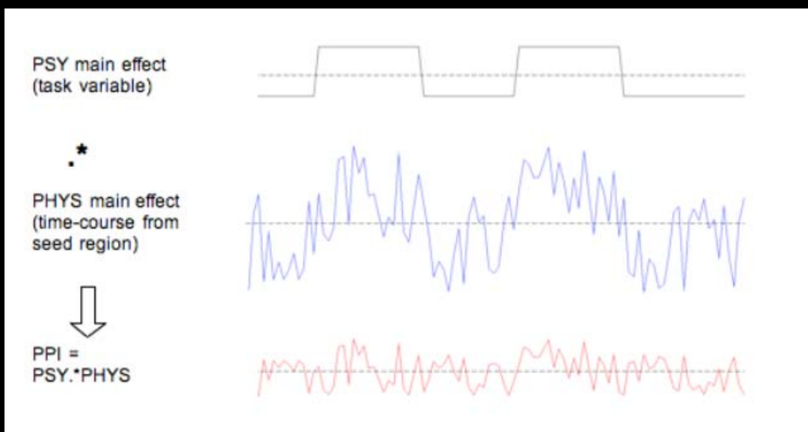
Dependencies of F0 mean and variations and emotional explicit tasks

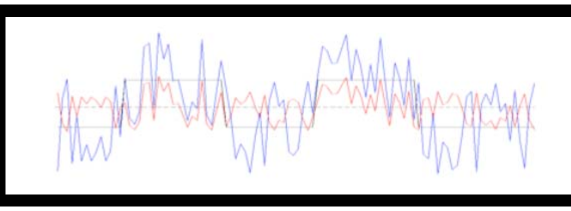


Fruehholz, Ceravolo, & Grandjean (2012). Cerebral Cortex

How the neuronal network(s) is(are) organized?

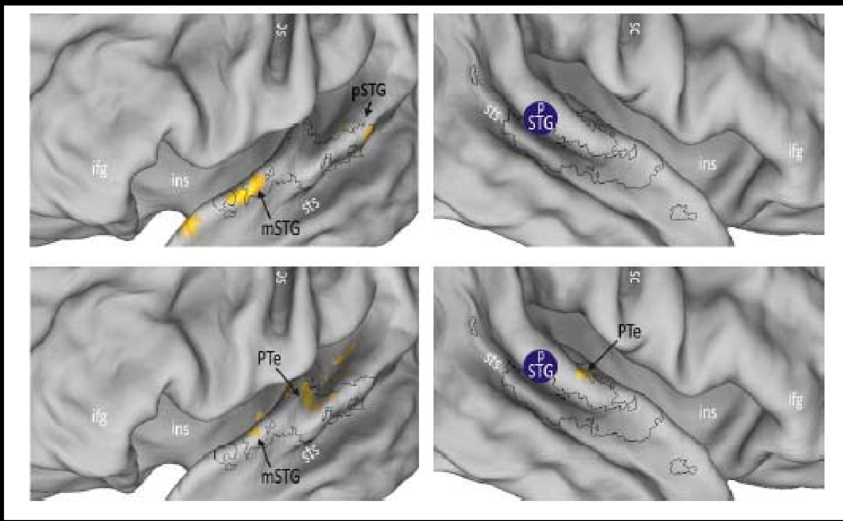
Psychophysiological interactions analysis - PPI





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

Explicit

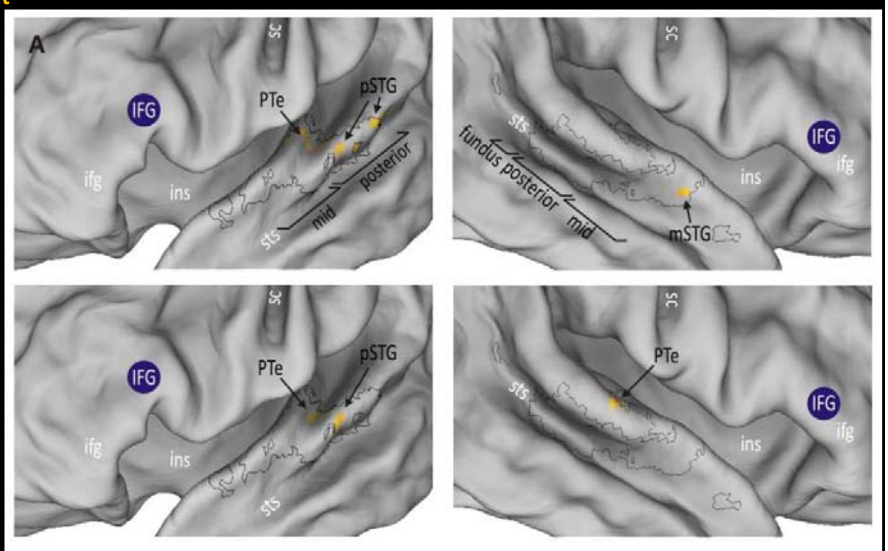


Implicit

Fruehholz, & Grandjean (2012). A refined fronto-temporal network for the decoding of emotional prosody. *Neuroimage*

Psychophysiological interactions analysis – PPI **bilateral IFG as seed region**

Explicit

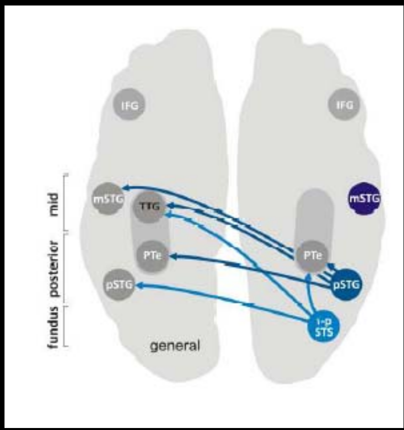


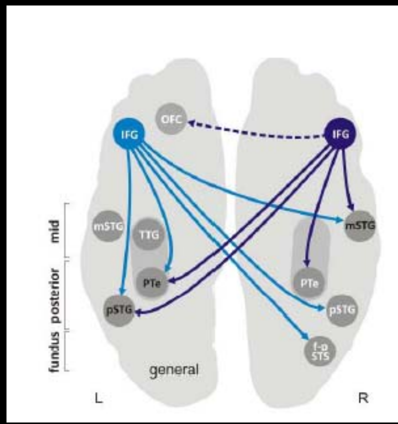
Implicit

Fruehholz, & Grandjean (2012). A refined fronto-temporal network for the decoding of emotional prosody. *Neuroimage.*

Psychophysiological interactions analysis – PPI

Summary

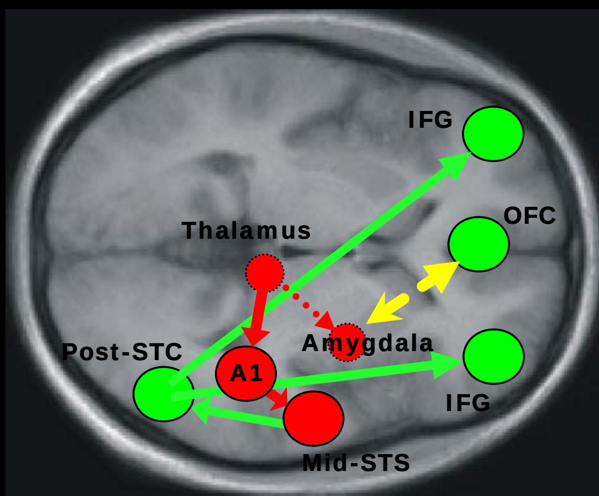




Fruehholz, & Grandjean (2012). A refined fronto-temporal network for the decoding of emotional prosody. *Neuroimage*.

emotional prosody

toward an integrative model of emotional prosody decoding

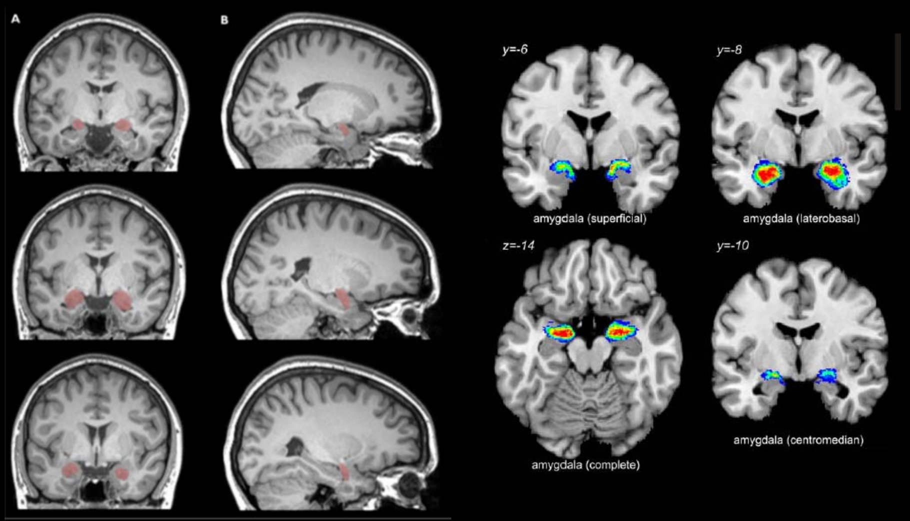


Bottom-up modulation (stimulus-driven)

Top-down modulation (task-dependent)

Wildgruber, Ethofer, Kreifelts, Grandjean (2008). Cerebral processing of emotional prosody: A network model based on fMRI studies. Proceedings of the International Conference of Speech Prosody.

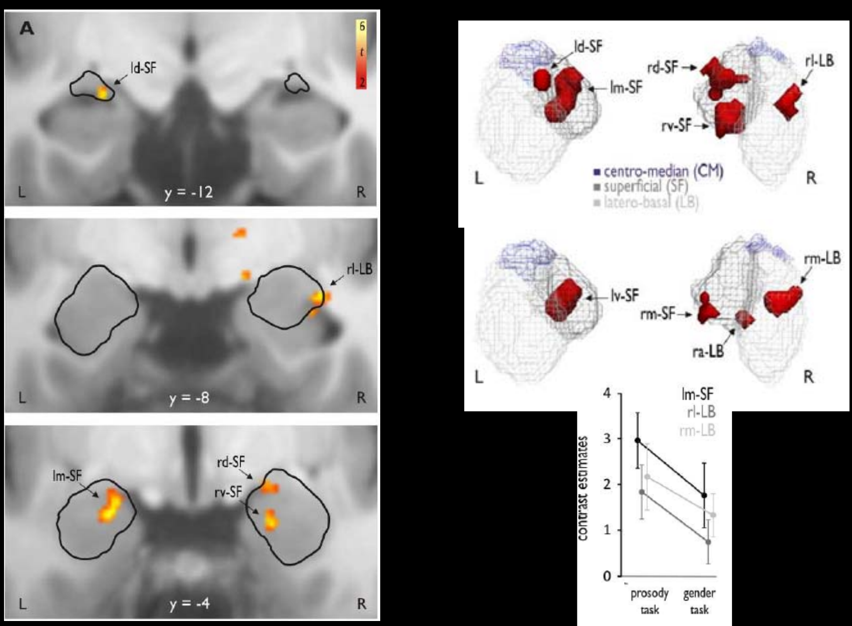
Delineation of the amygdala for each participant



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

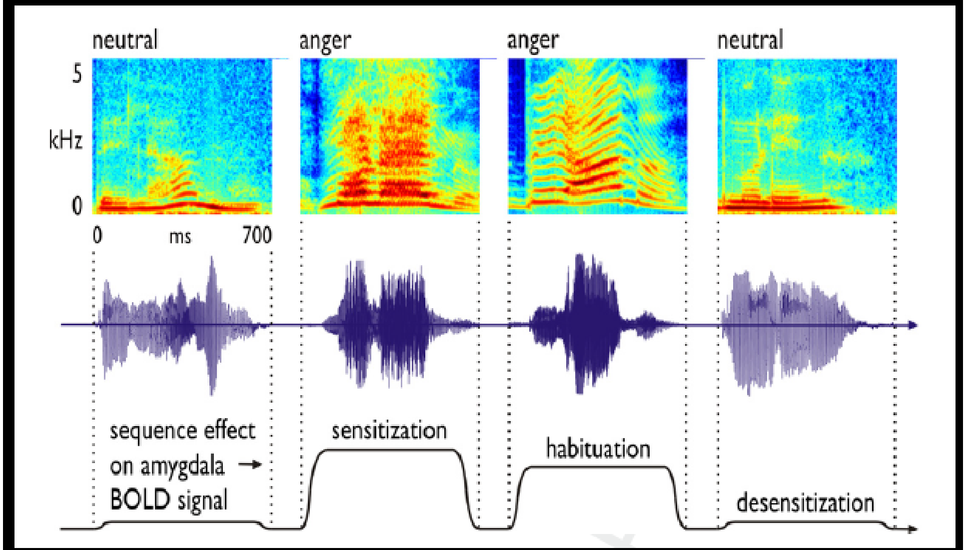
Fruehholz & Grandjean (2013). Different amygdala subregions process and rapidly adapt to threatening voices. *Cortex*.

Modulation of activity in subregions of Amygdala: Anger versus Neutral

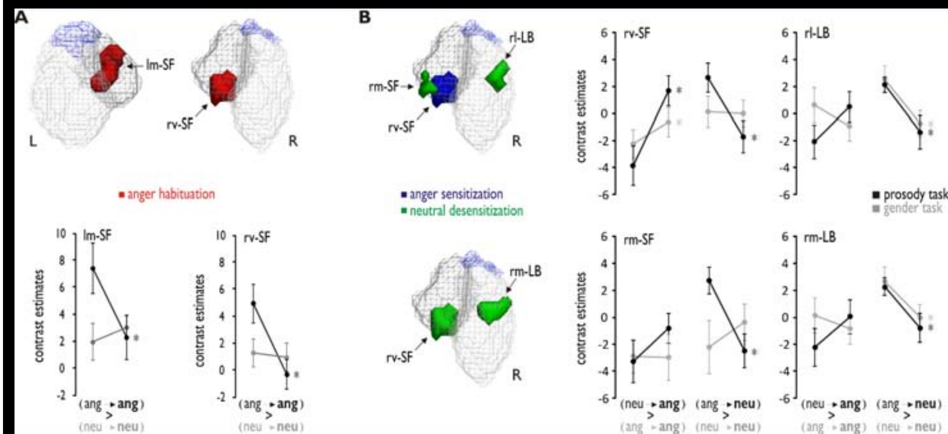


Fruehholz & Grandjean (in press). Different amygdala subregions process and rapidly adapt to threatening voices. *Cortex*.

Amygdala and habituation – sensitization - desensitization



Amygdala and habituation – sensitization - desensitization

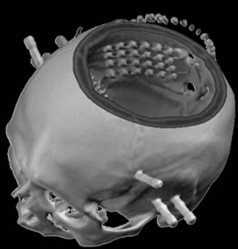


The Amygdala - Orbito-frontal coupling

Intracranial recordings

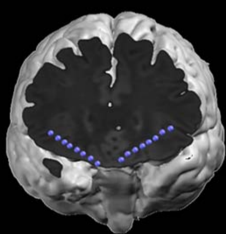
local field potentials

depth electrodes of interest



Orbitofrontal cortex

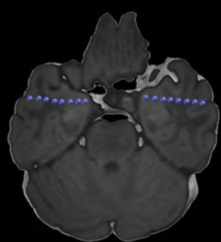
RightOFC



Left OFC

Amygdala

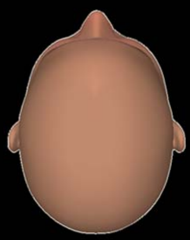
Left A



Right A

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.

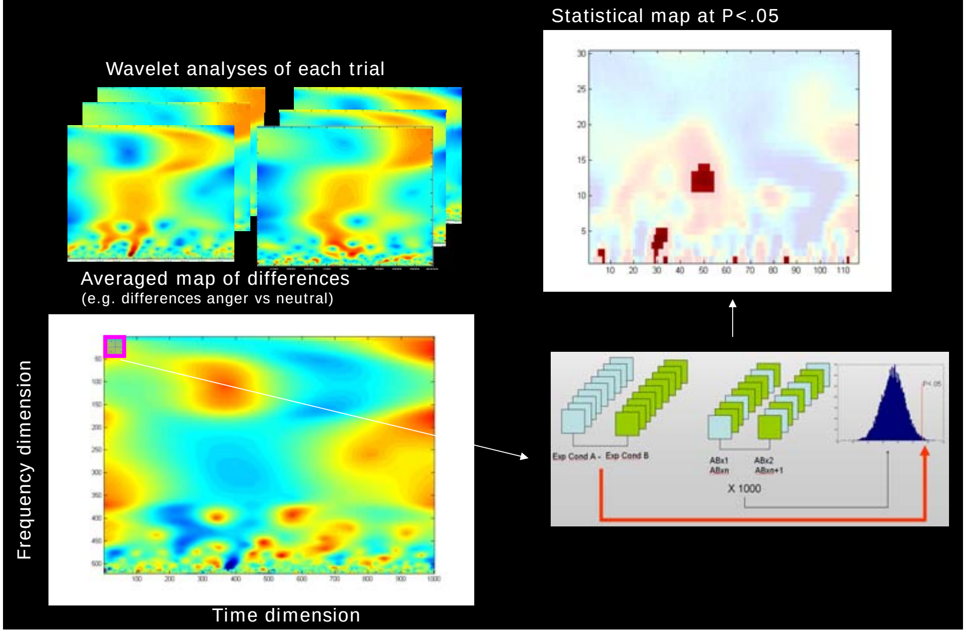
Presentation of binaural sounds using headphones (750ms)

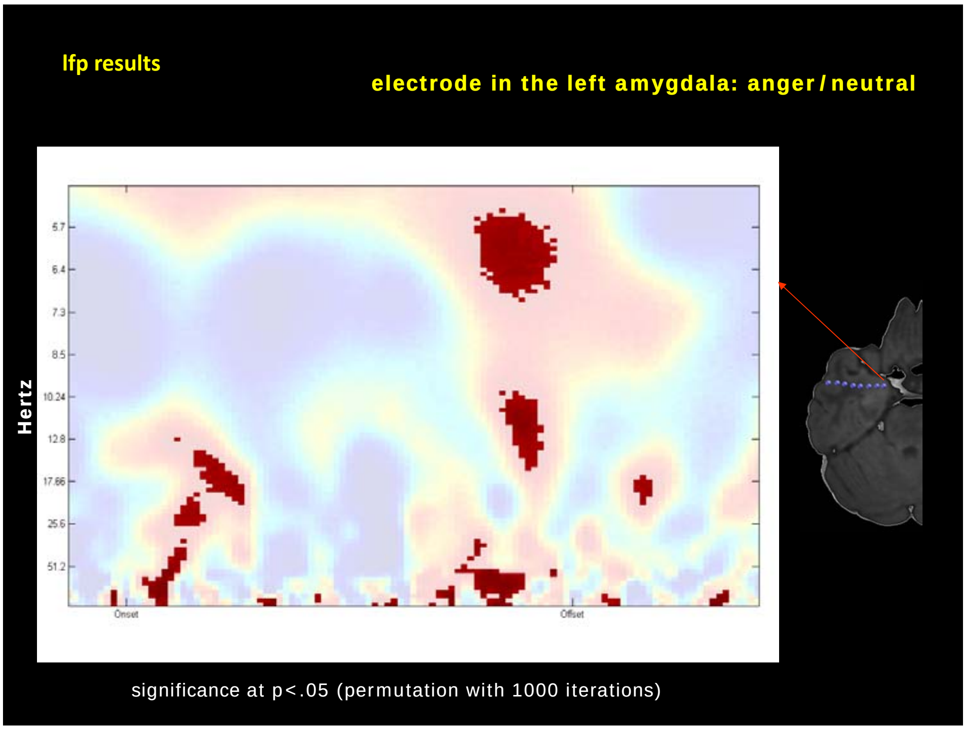
30 trials of each emotional types (angry, happiness, sadness, fearful, neutral) in three blocks, presented in pseudo-randomly order
Control condition: extracted envelope of the sounds + white noise/mean F0 (static)/F0 dynamic (changes of F0 in function of the time)

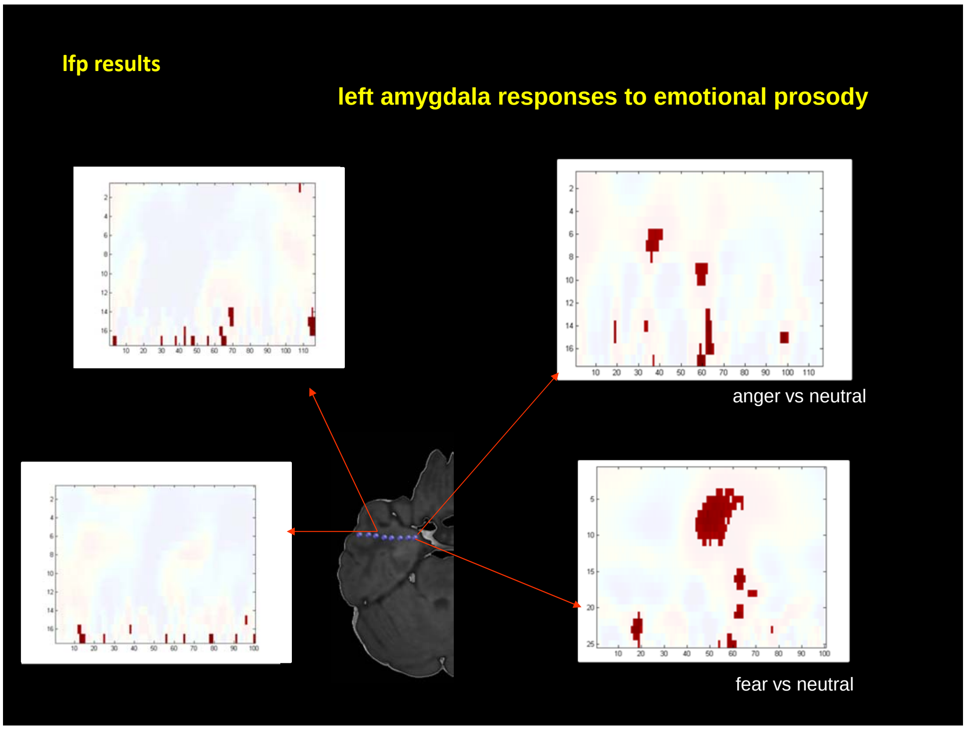
Grandjean, et al., in preparation

lfps analysis

permutation tests on time-frequency space

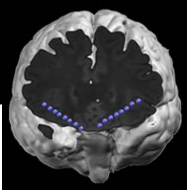



lfp results
electrode in the left amygdala: anger / neutral
Hertz
5.7
6.4
7.3
8.5
10.24
12.8
17.66
25.6
51.2
Onset
Offset
significance at p<.05 (permutation with 1000 iterations)

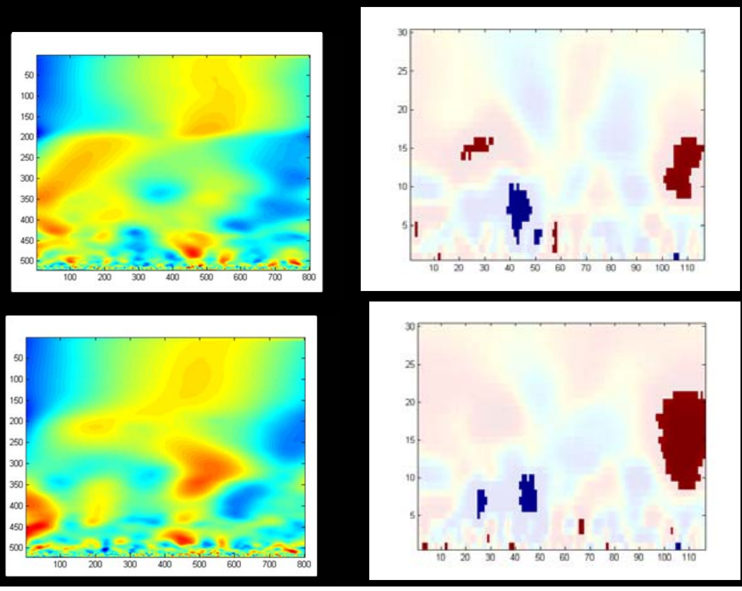

lfp results
left amygdala responses to emotional prosody
anger vs neutral
fear vs neutral

lfp results

test of the LFPs of the left medial OFC



more medial contact

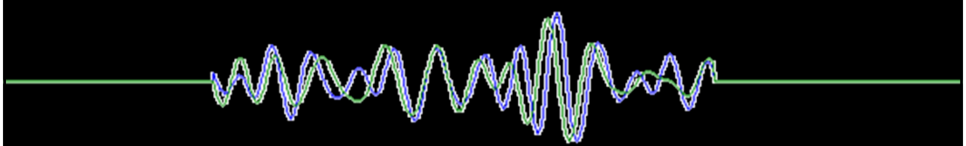


bilateral test
P<.025

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).

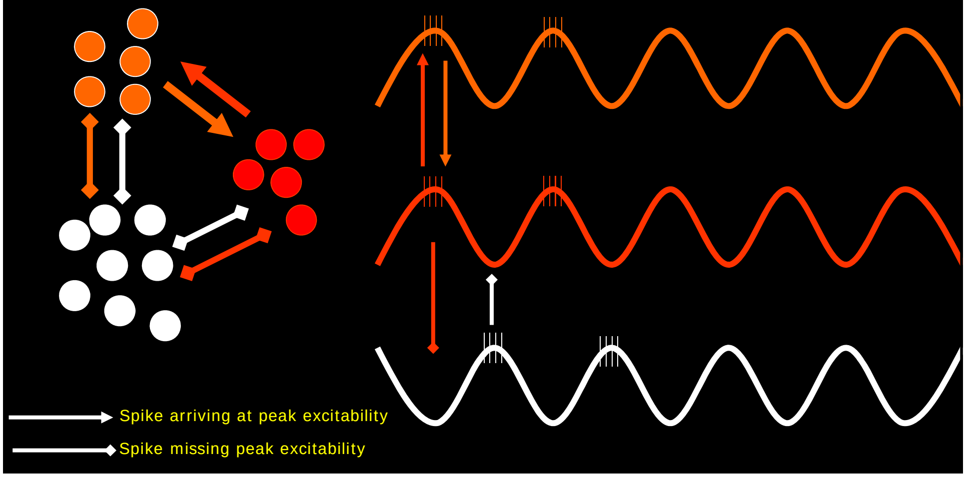


Grandjean, Sander, & Scherer (2008). *Consciousssness and Cognition.*

neuronal synchronization

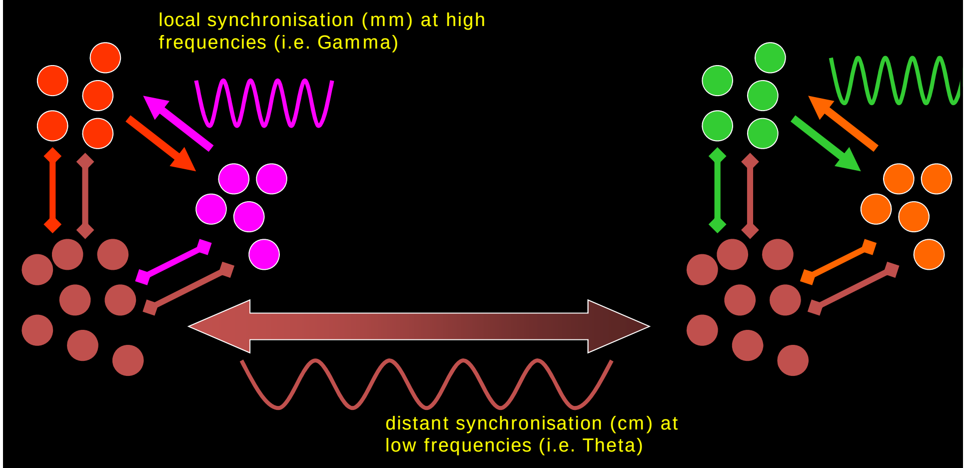
neuronal oscillations and synchronization of distant neural networks

model “Communication Through Coherence” (CTC, Fries, 2005, *TICS*)



neuronal synchronization

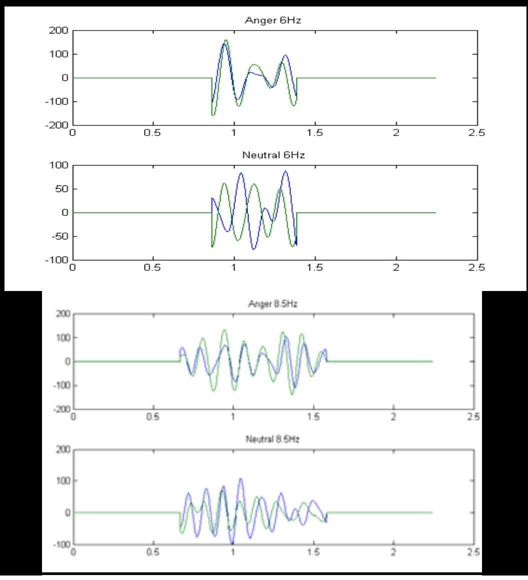
neuronal oscillations and synchronization of distant neural networks

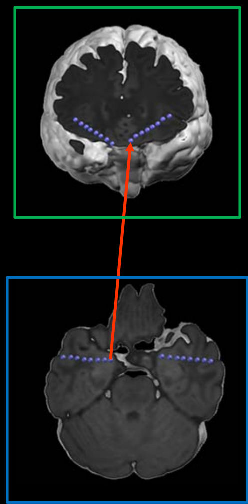


Guderian & Duzel 2005, *Hippocampus*; Canolty et al., 2006, *Science; Fries et al., 2007, Science;* Canolty & Knight, 2010, *TICS.*

neuronal synchronization

measures of the phase synchrony of oscillations of distant brain regions

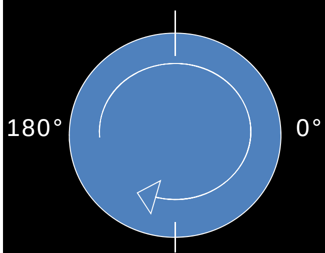


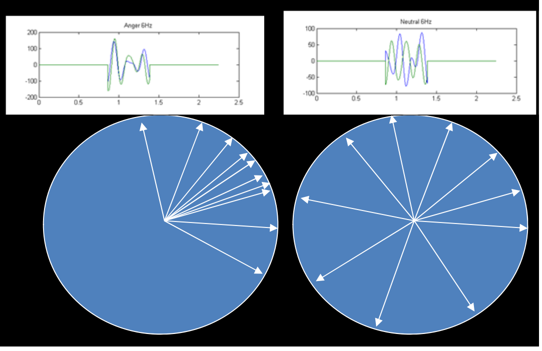


neuronal synchronization

measures of the phase synchrony of brain oscillations

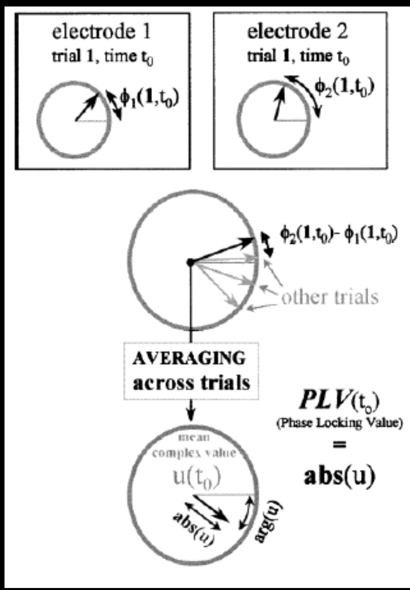
in the following analyses we used a complex Gabor wavelet (+- 2Hz) to compute the phase locking value (PLV), it was computed at each frequency from 5 Hz to 40 Hz.





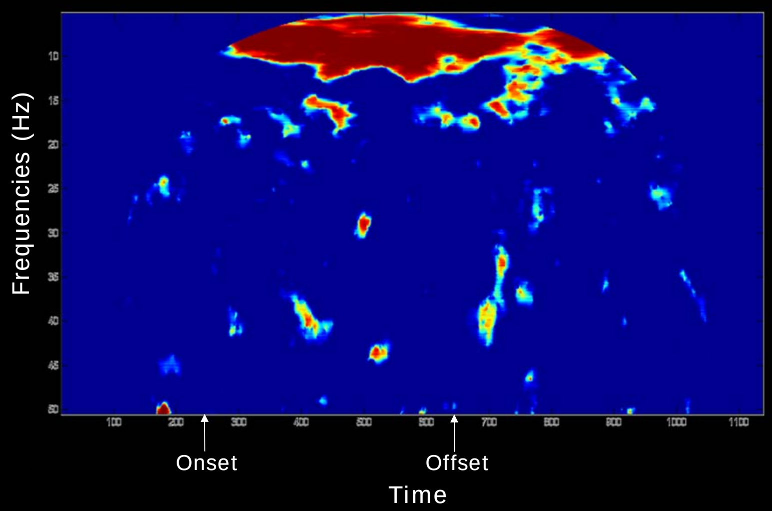
neuronal synchronization

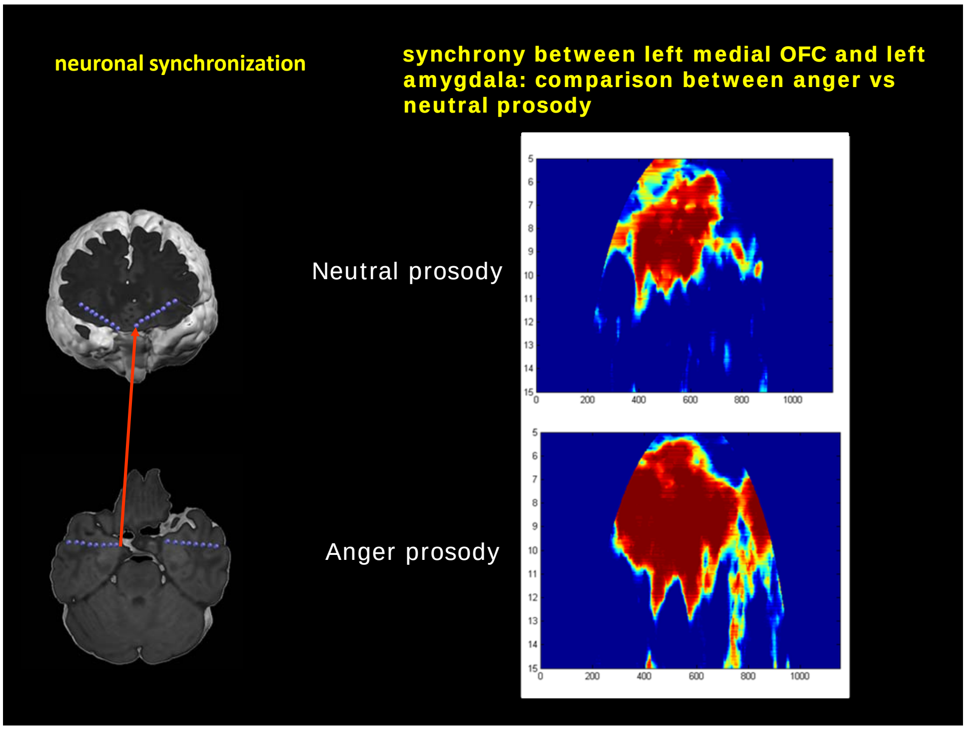
measures of the phase synchrony of brain oscillations

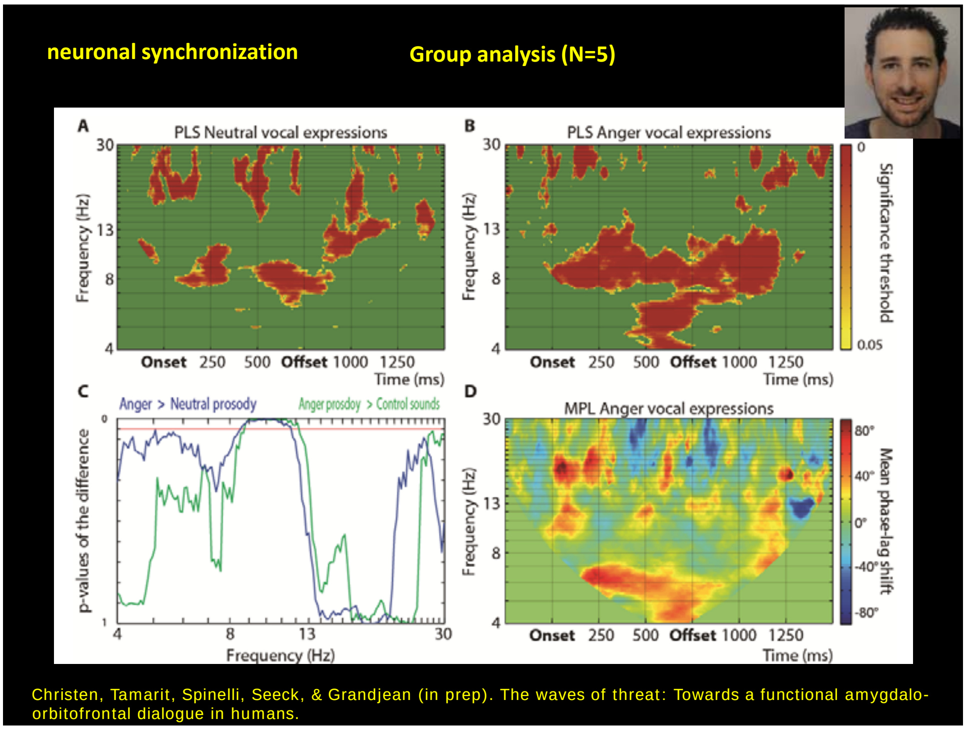


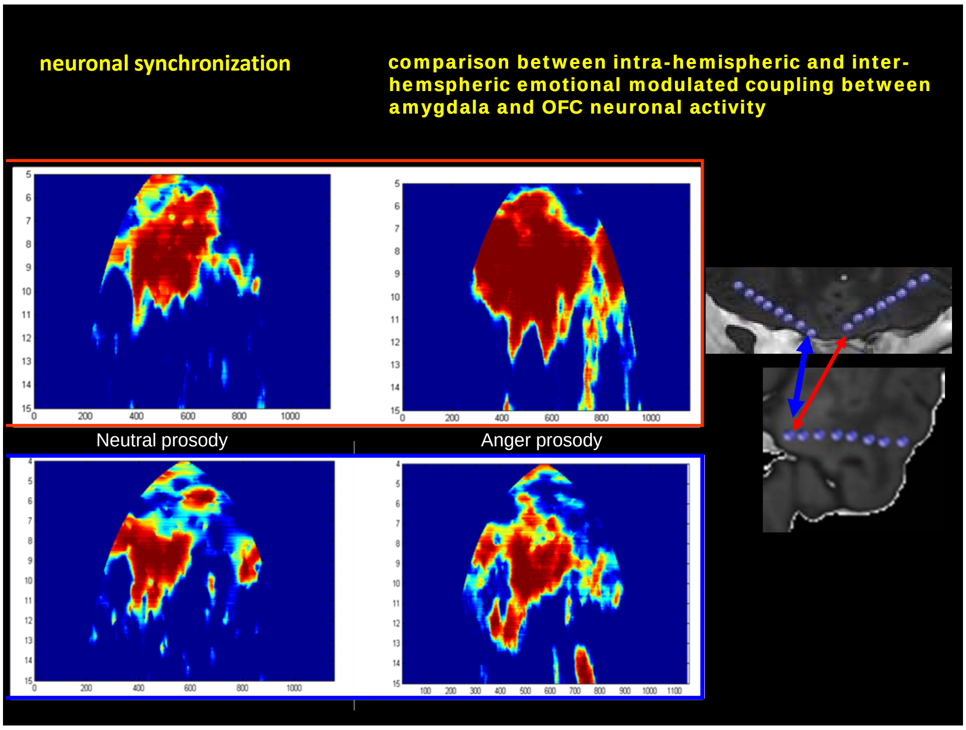
neuronal synchronization

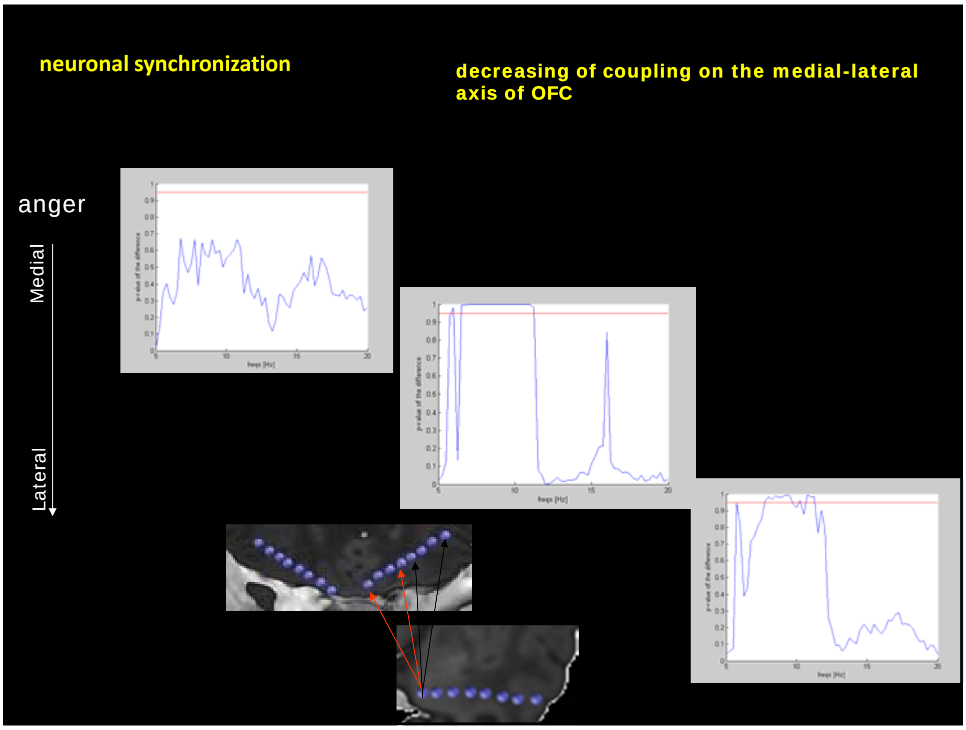
PLS between left amygdala and left medial OFC during angry prosody exposure




neuronal synchronization
synchrony between left medial OFC and left amygdala: comparison between anger vs neutral prosody
Neutral prosody
Anger prosody


neuronal synchronization
Group analysis (N=5)
A
PLS Neutral vocal expressions
Frequency (Hz)
Onset 250 500 Offset 1000 1250
Time (ms)
B
PLS Anger vocal expressions
Frequency (Hz)
Onset 250 500 Offset 1000 1250
Time (ms)
Significance threshold
0
0.05
C
Anger > Neutral prosody
Anger prosdoy > Control sounds
p-values of the difference
Frequency (Hz)
D
MPL Anger vocal expressions
Frequency (Hz)
Onset 250 500 Offset 1000 1250
Time (ms)
Mean phase-lag shift
80°
40°
0°
-40°
-80°
Christen, Tamarit, Spinelli, Seeck, & Grandjean (in prep). The waves of threat: Towards a functional amygdalo-orbitofrontal dialogue in humans.

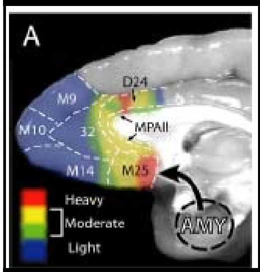

neuronal synchronization
comparison between intra-hemispheric and inter-hemspheric emotional modulated coupling between amygdala and OFC neuronal activity
Neutral prosody
Anger prosody

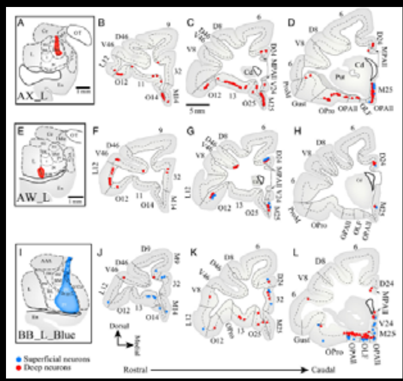

neuronal synchronization
decreasing of coupling on the medial-lateral axis of OFC
anger
Medial
Lateral

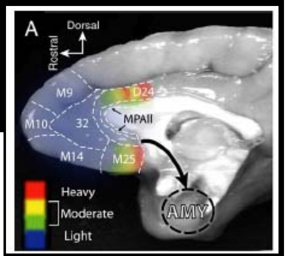
neuronal synchronization

relations amygdala - OFC

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

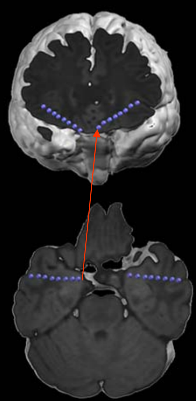


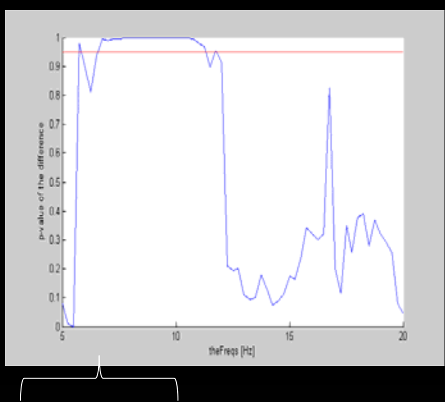


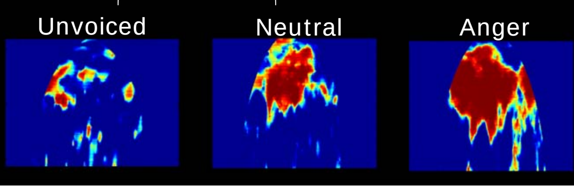


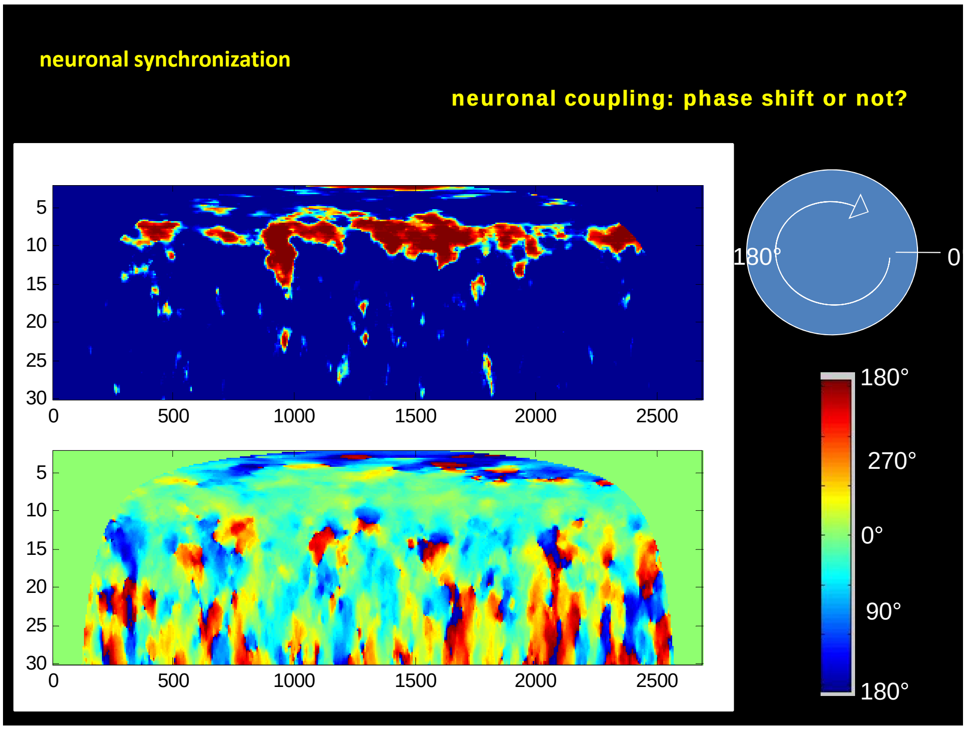
neuronal synchronization

neutral vs Control stimuli Unvoiced Envelope

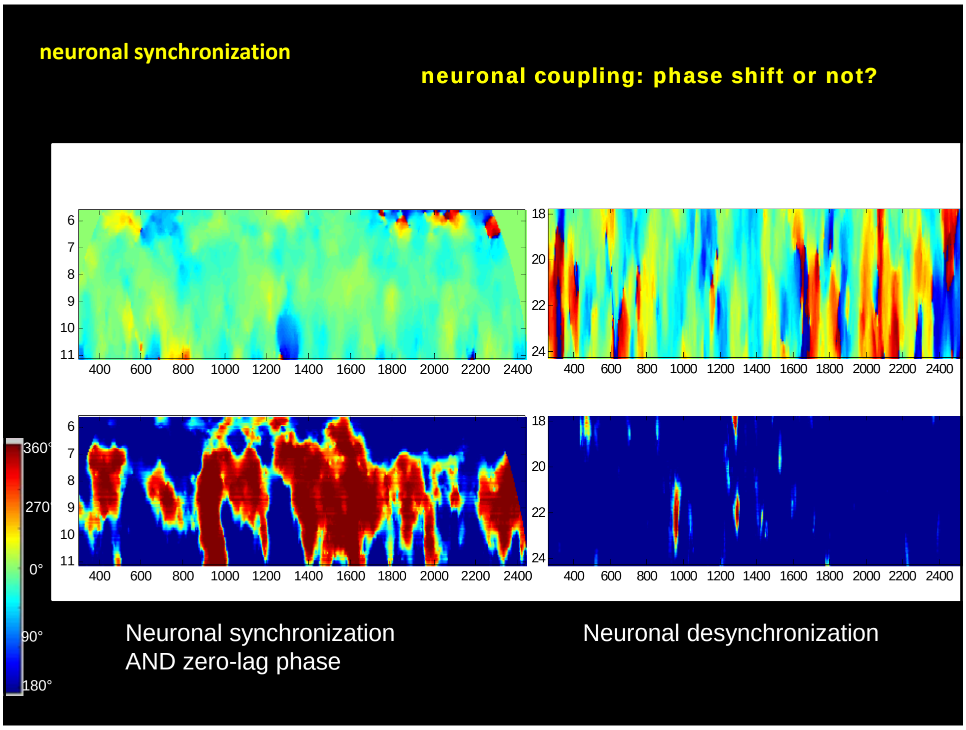




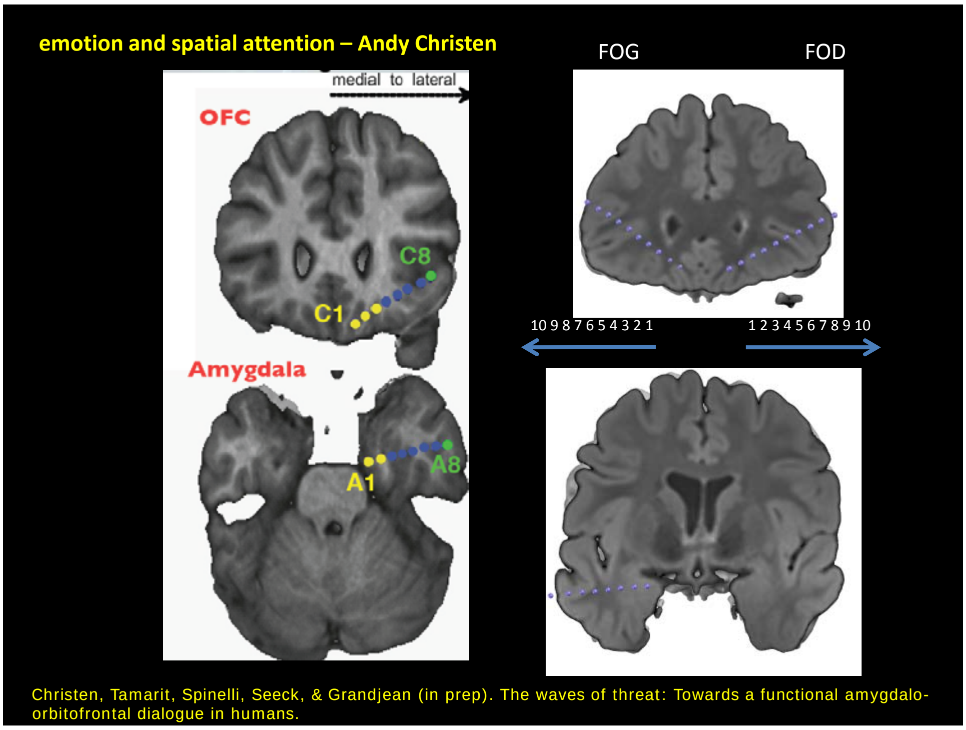




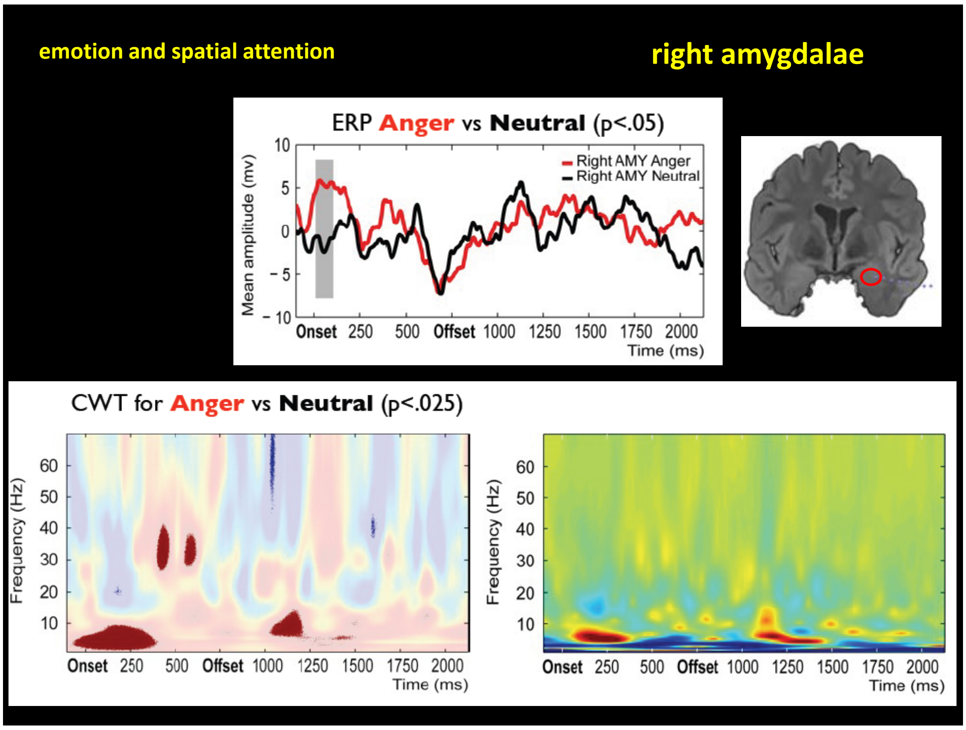
neuronal synchronization
neuronal coupling: phase shift or not?
180°
0
180°
270°
0°
90°
180°



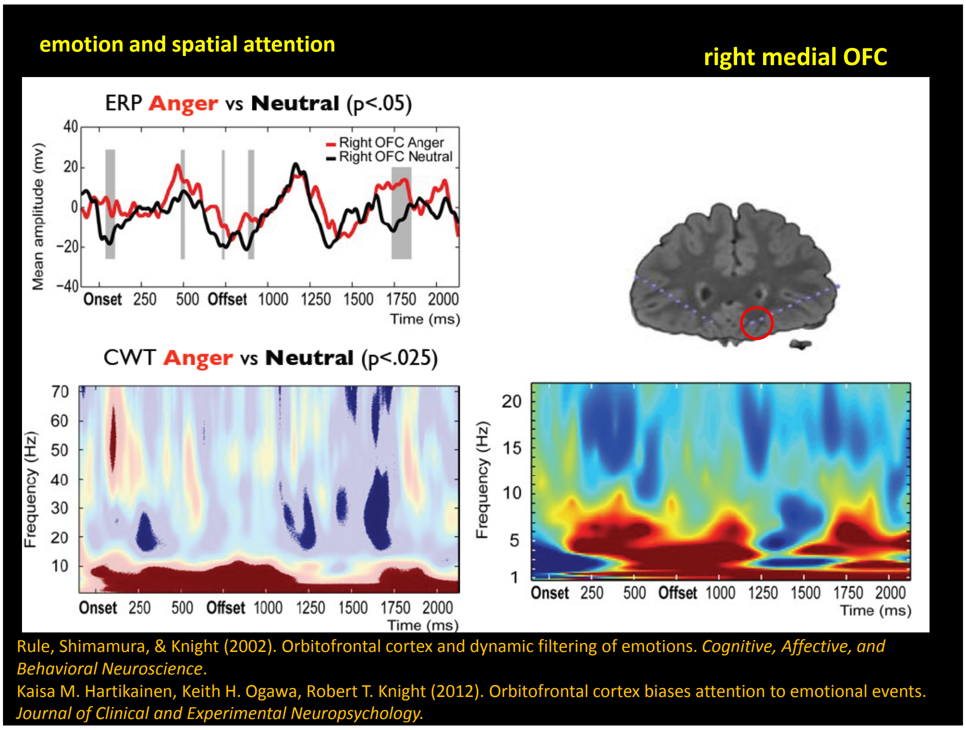
neuronal synchronization
neuronal coupling: phase shift or not?
360°
270°
0°
90°
180°
Neuronal synchronization
AND zero-lag phase
Neuronal desynchronization

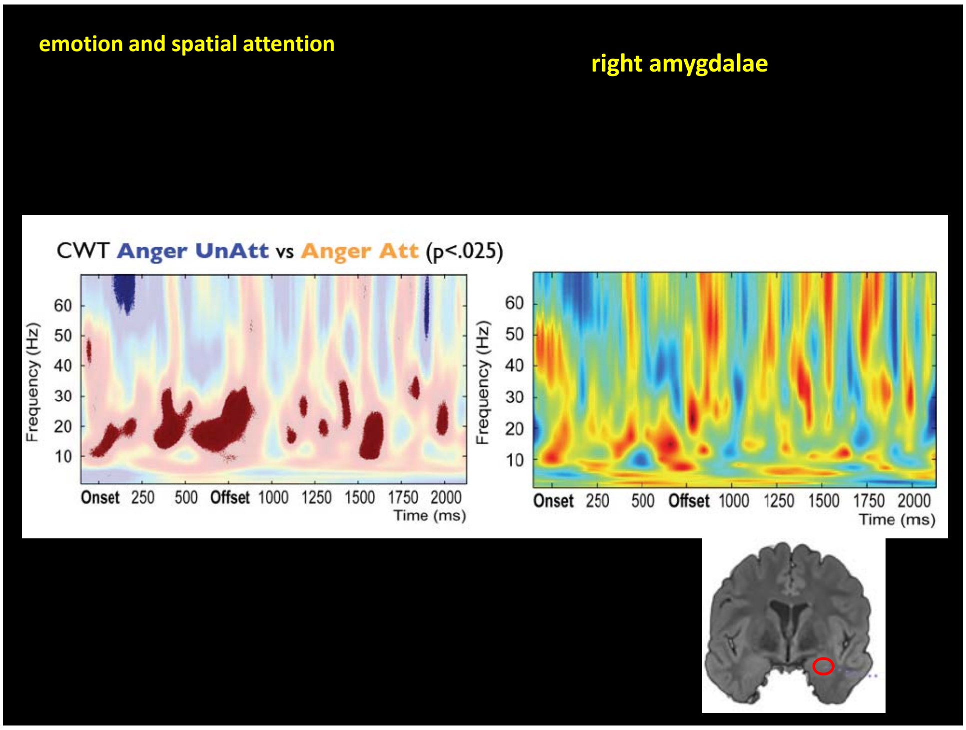


emotion and spatial attention – Andy Christen
medial to lateral
OFC
C8
C1
Amygdala
A1
A8
FOG
FOD
10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10
Christen, Tamarit, Spinelli, Seeck, & Grandjean (in prep). The waves of threat: Towards a functional amygdalo-orbitofrontal dialogue in humans.



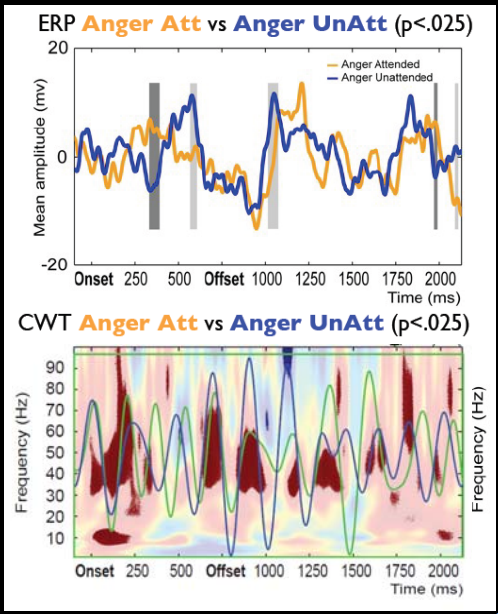
emotion and spatial attention
right amygdalae
ERP Anger vs Neutral (p<.05)
Right AMY Anger
Right AMY Neutral
Mean amplitude (mv)
10
5
0
−5
−10
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)
CWT for Anger vs Neutral (p<.025)
Frequency (Hz)
60
50
40
30
20
10
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)

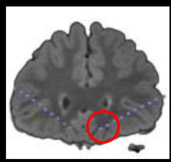

emotion and spatial attention
right medial OFC
ERP Anger vs Neutral (p<.05)
Right OFC Anger
Right OFC Neutral
Mean amplitude (mv)
40
20
0
−20
−40
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)
CWT Anger vs Neutral (p<.025)
Frequency (Hz)
70
60
50
40
30
20
10
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)
Frequency (Hz)
20
15
10
5
1
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)
Rule, Shimamura, & Knight (2002). Orbitofrontal cortex and dynamic filtering of emotions. *Cognitive, Affective, and Behavioral Neuroscience*.
Kaisa M. Hartikainen, Keith H. Ogawa, Robert T. Knight (2012). Orbitofrontal cortex biases attention to emotional events. *Journal of Clinical and Experimental Neuropsychology.*


emotion and spatial attention
right amygdalae
CWT Anger UnAtt vs Anger Att (p<.025)
Frequency (Hz)
60
50
40
30
20
10
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)
Frequency (Hz)
60
50
40
30
20
10
Onset 250 500 Offset 1000 1250 1500 1750 2000
Time (ms)

emotion and spatial attention

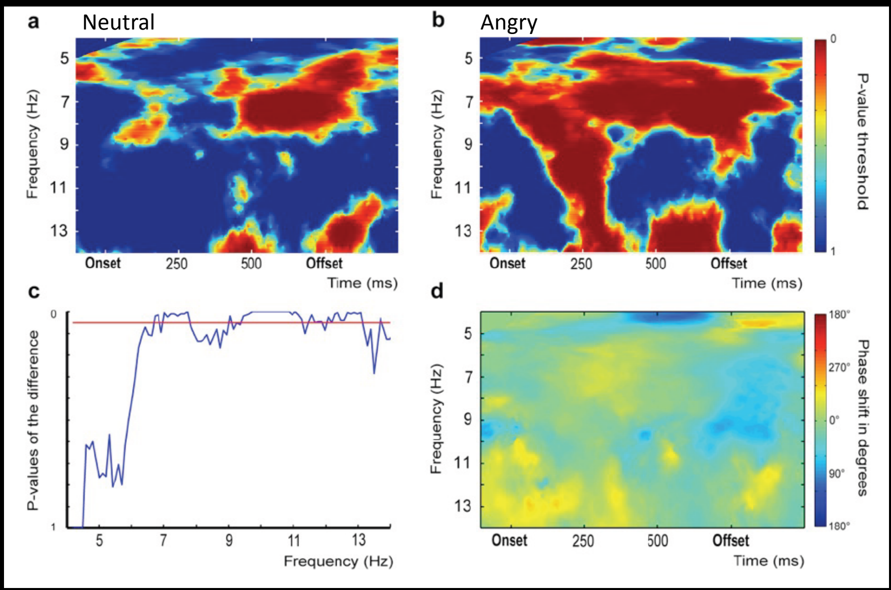
right medial OFC





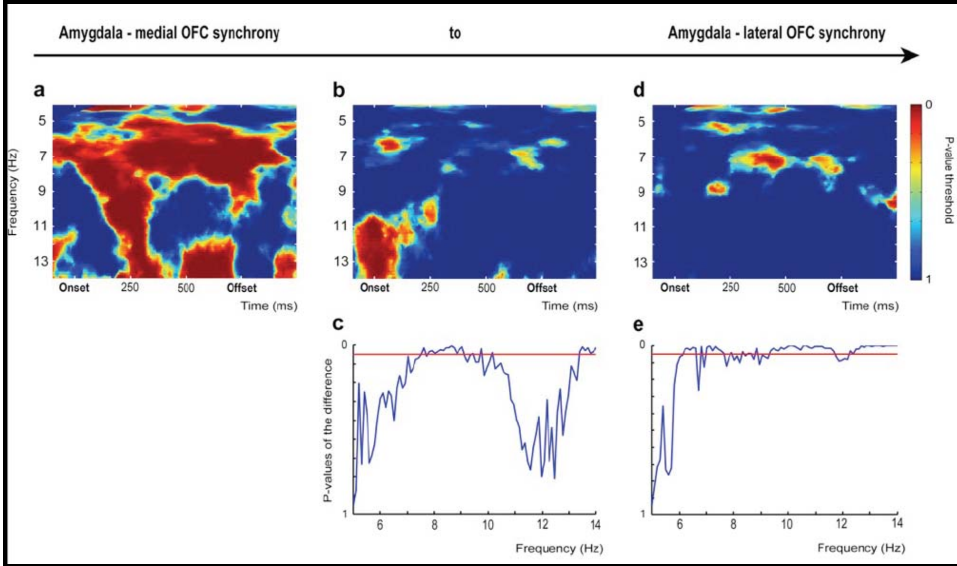
emotion and spatial attention

amygdalo-OFC neuronal synchronization for anger vs neutral



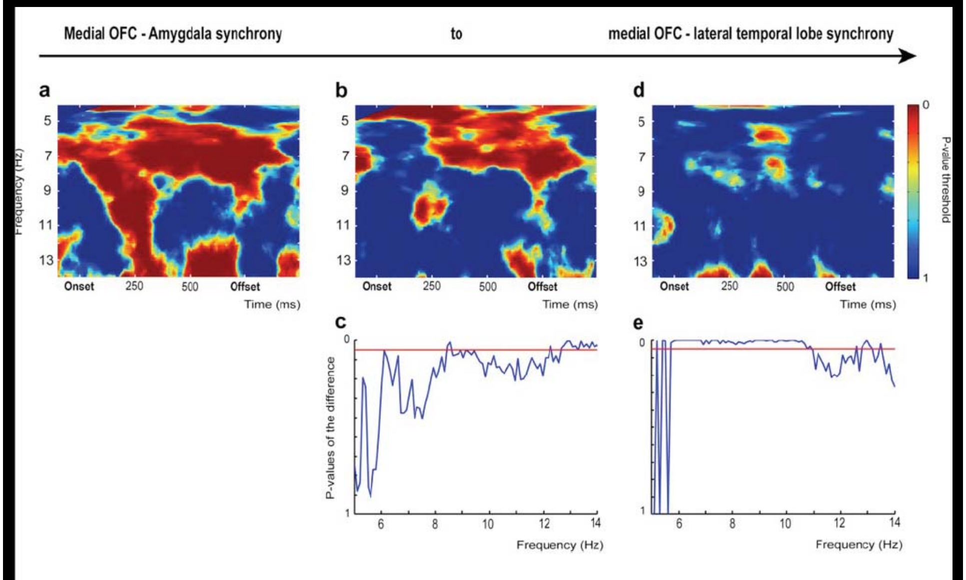
emotion and spatial attention

amygdalo-OFC neuronal synchronization

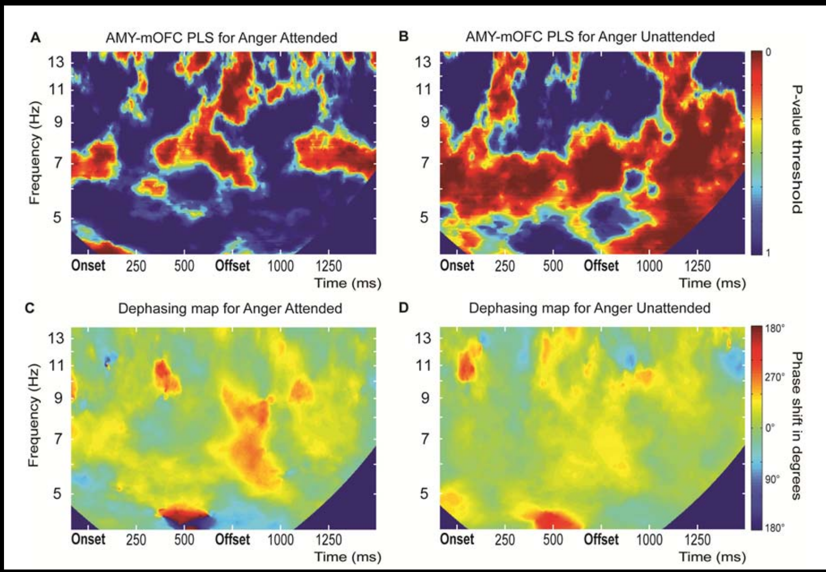


emotion and spatial attention

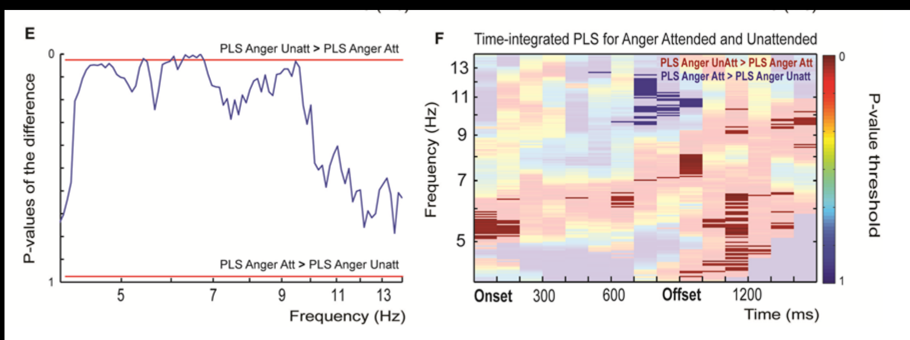
amygdalo-OFC neuronal synchronization



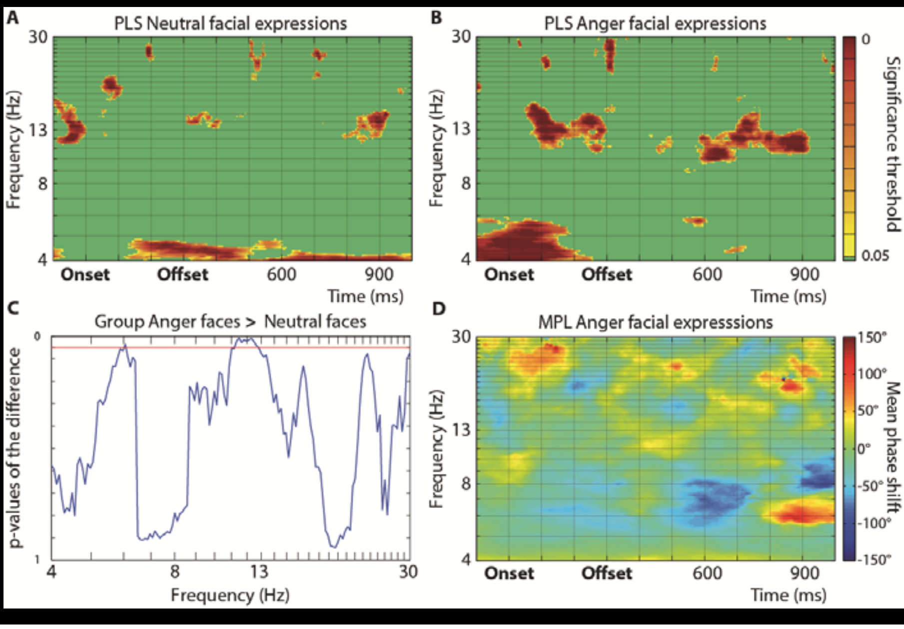
Modulation of synchronization by attention



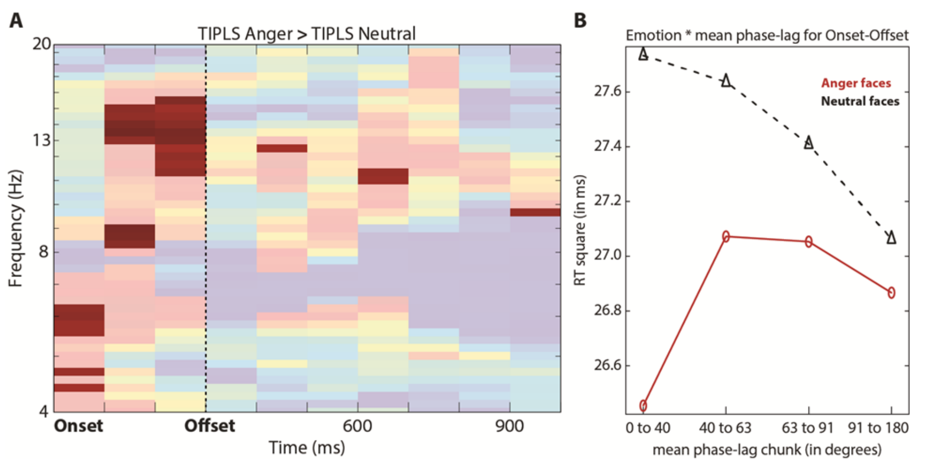
Unfolding of neuronal synchronization and attention



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.