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Emotion induced by auditory roughness modulates multisensory integration in relation with the body

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Introduction

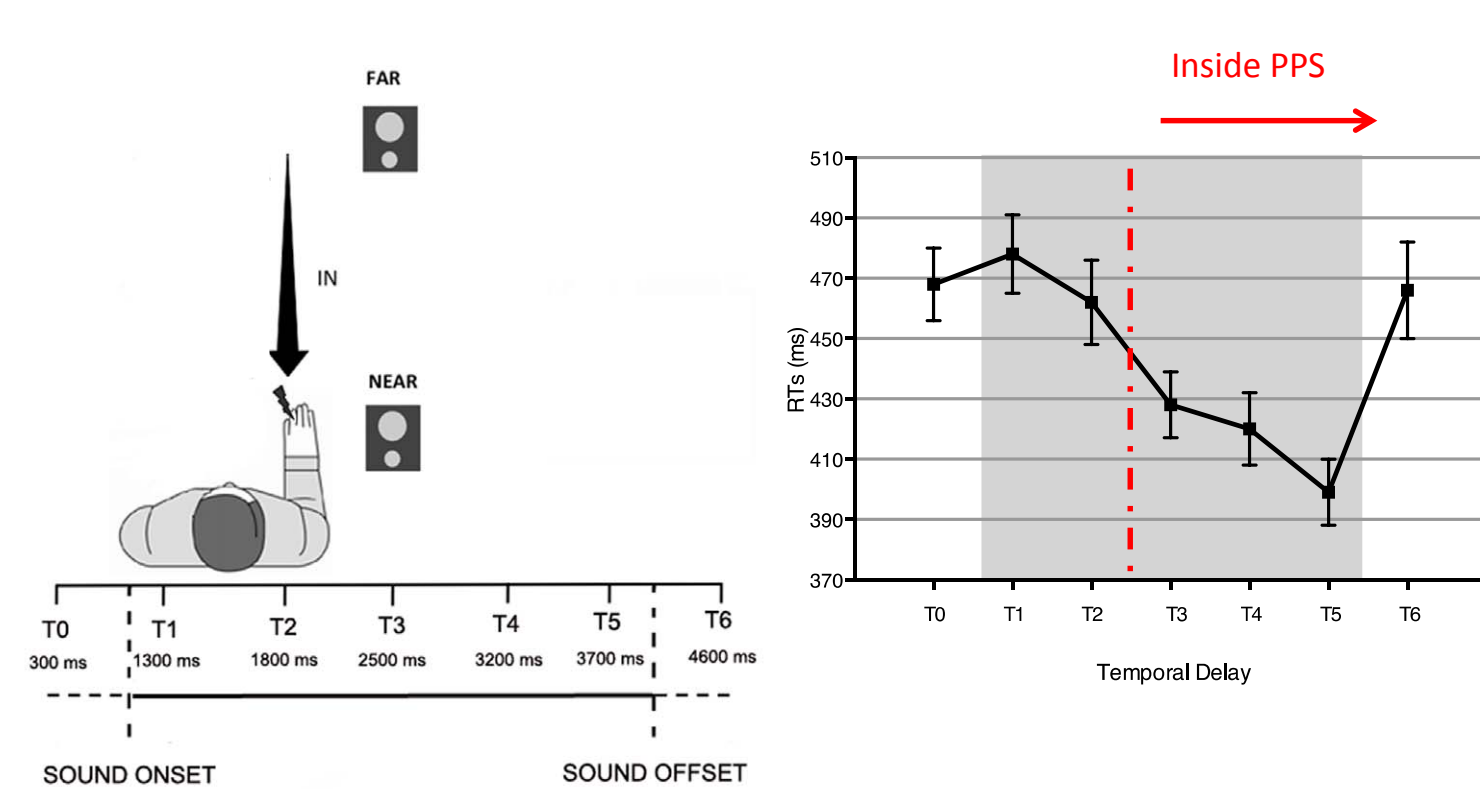
Peri-personal space (PPS) is defined as the space immediately surrounding our bodies [1], which is critical for our interactions with the external world. This space near the body, which is coded by a dedicated network of multisensory neurons, is thought to play a role in the protection of the body. PPS multisensory coding is known to be modulated by the presence of threatening elements in the environment [e.g. 2, 3, 4].

Recently, it has been evidenced that alarming sounds such as human screams comprise an acoustic attribute (amplitude modulation in the 30–150Hz range), which corresponds to the perception of roughness. Roughness seems to be linked to a more intense induction of fear, behavioral gains and a higher activation in cerebral areas involved in fear and danger processing [5]. Therefore, we hypothesized that if the presence of roughness confers to sounds an emotional quality, it should impact the integration of multisensory stimuli related to the coding of the space around the body. To test this hypothesis, we explored whether auditory-tactile integration could be modified by the auditory attribute of roughness.

Methods

Studying audio-tactile integration in relation with the body:

Canzoneri et al.'s method [6]



“Participants responded to a tactile stimulus administered to the hand at different delays from the onset of a task-irrelevant dynamic sound (pink noise) which gave the impression of a sound source approaching or receding from the subjects. The moving auditory stimulus sped up the processing of the tactile stimulus to the hand as long as it was perceived at a limited distance from the hand; that is within the boundaries of the PPS. Thus, the critical distance where sounds starts speeding up tactile reaction can be considered as a proxy of PPS boundaries.”

Participants:

Thirty-eight healthy right-handed participants (19 women; age: $M \pm SD = 24.5 \pm 4.2$, range 18-37)

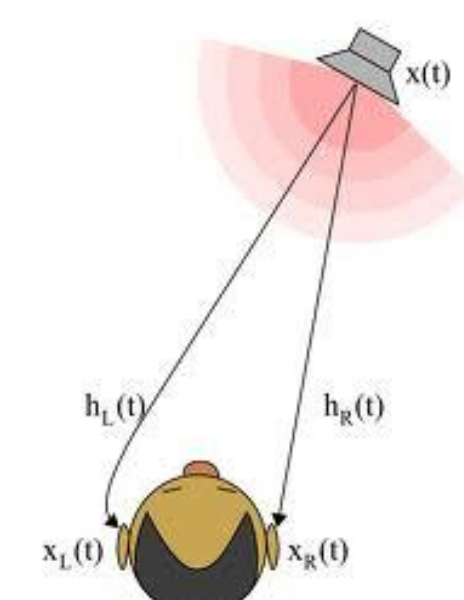
Stimuli:

Tactile stimulus: vibratory stimulus, 20ms, 250Hz.

Auditory stimuli: continuous synthetic and meaningless sounds (duration 3000ms)

- **Non Rough** sound (harmonic sound, $f_0=500\text{Hz}$)
- **Rough** sound (the same harmonic sound amplitude-modulated at 70Hz)

⇒ Sound spatialization, looming stimuli (5m in 3000ms)



The auditory stimuli were processed through binaural rendering using non-individual Head Related Transfer Functions (HRTF) and were presented through Sennheiser HD650 headphones. With this procedure, the virtual sound source location can be manipulated.

Setup & Protocol:

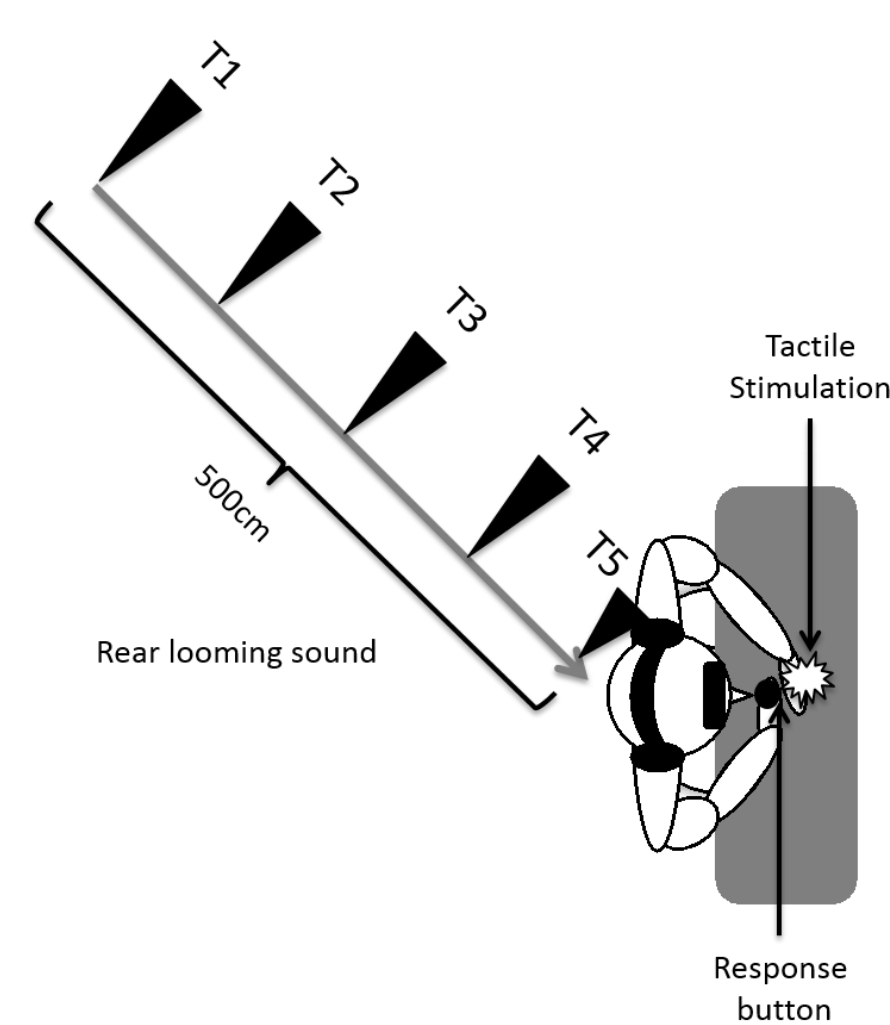
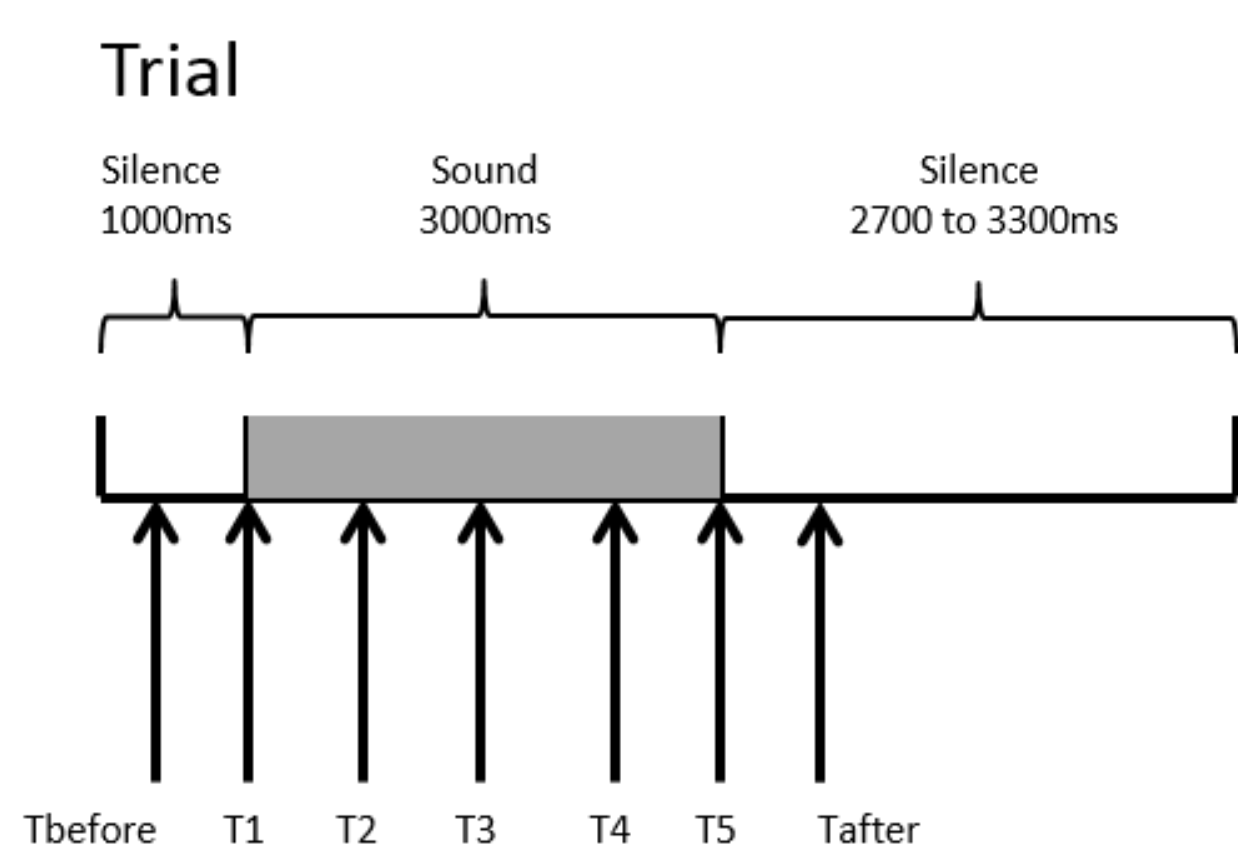
Task: Detect the tactile stimuli and ignore the irrelevant sound

14 Conditions, Factors:

- DELAY (7 levels: Tbefore, T1, T2, T3, T4, T5, Tafter)
- SOUND TYPE (2 levels: rough/ non-rough sound)

⇒ 20 target stimuli per condition. 280 trials with a tactile target, randomly intermingled with 40 catch trials (no tactile stimulus).

⇒ 10 blocks of 32 trials (4 minutes each).

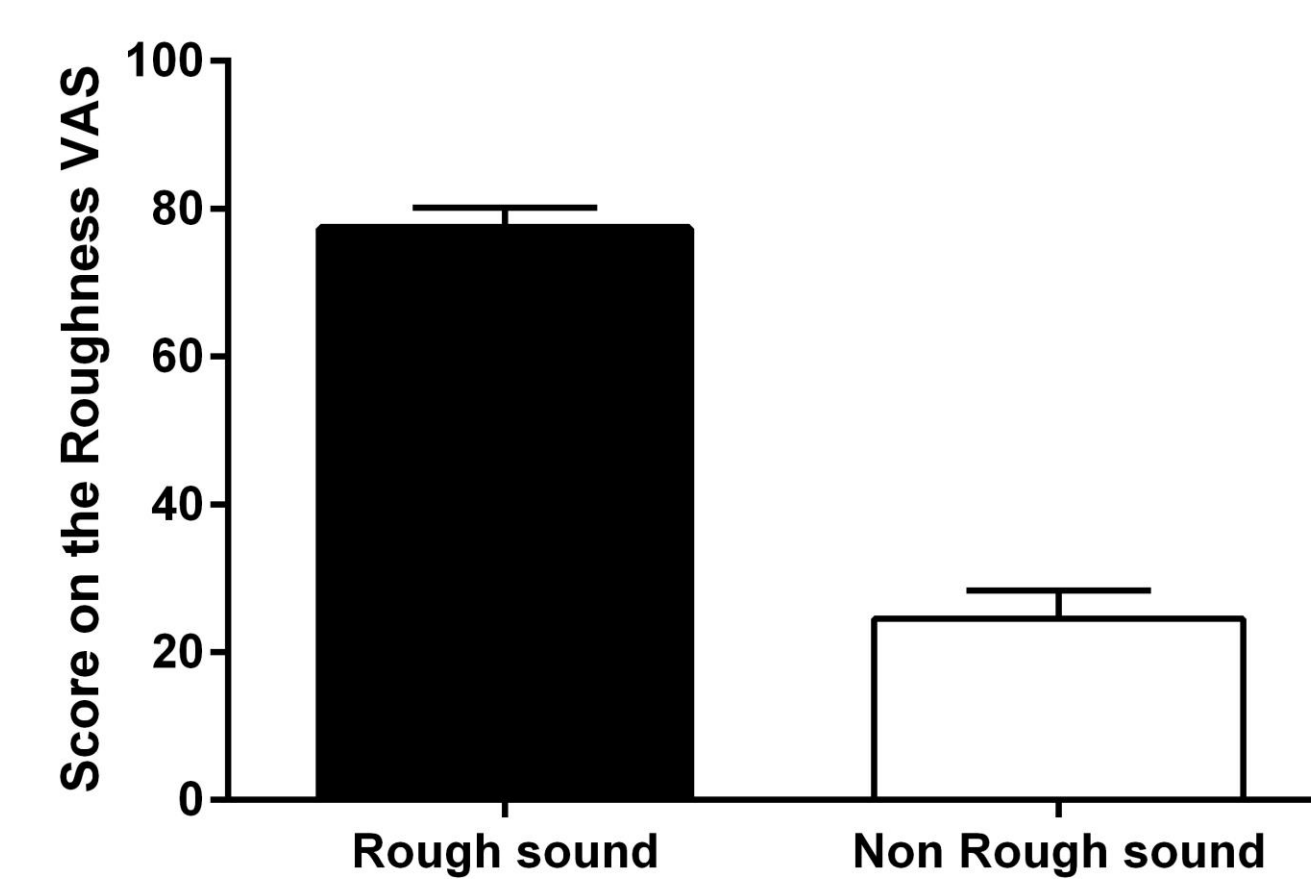


Tx: Delay between sound onset and tactile stimulation
 Localization of the sound source when tactile stimulation occurs, for each Tx

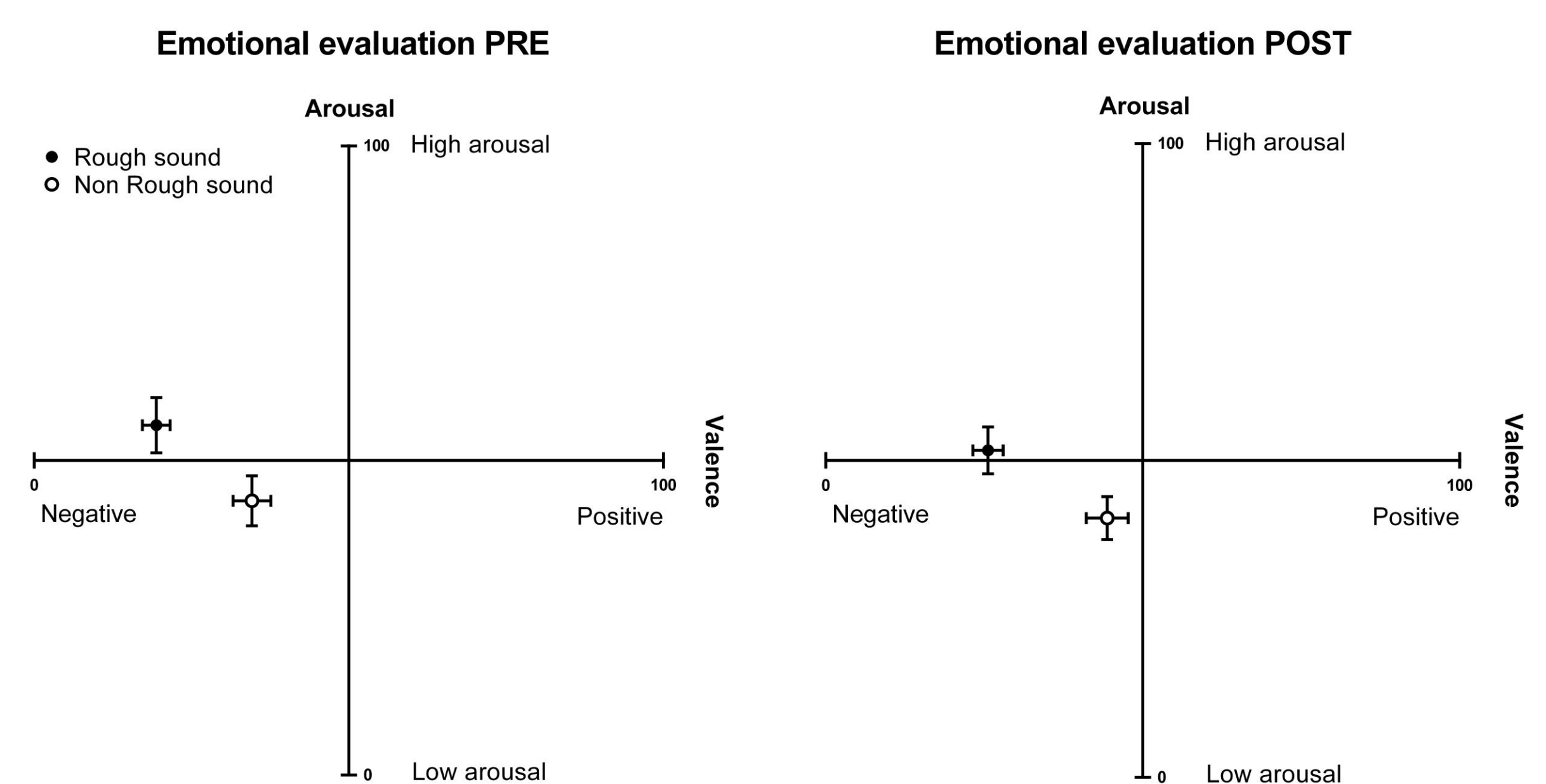
Results

Evaluation of auditory stimuli:

⇒ Roughness evaluation of the static auditory stimuli (VAS)



⇒ Emotional evaluation of the static auditory stimuli (VAS)



Analysis of RTs:

Mean RTs to tactile target were calculated for each of the 14 conditions, for each subject.

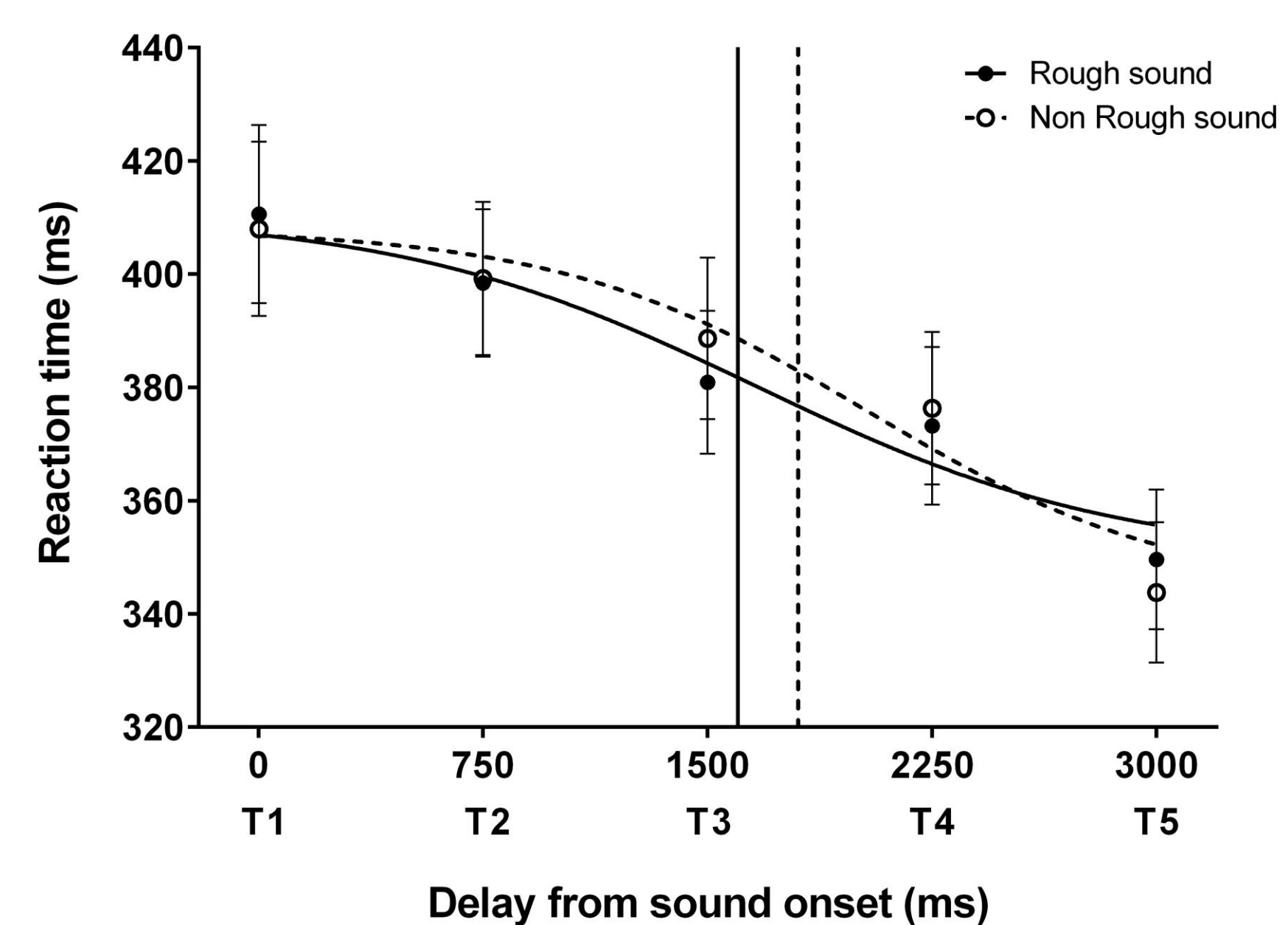
ANOVA on RTs in the bimodal trials (N=38):

- within subject factor DELAY (5 levels: T1, T2, T3, T4, T5)
- within subject factor SOUND TYPE (2 levels: rough/ non-rough sound)

⇒ No main effect of SOUND TYPE ($F_{(1, 37)} = 0.40, p = 0.532$)

⇒ Effect of DELAY ($F_{(4, 148)} = 63.14, p < 0.001$)

⇒ Effect of the interaction DELAY*SOUND TYPE ($F_{(4, 148)} = 3.02, p = 0.020$)



Sigmoid fitting of participants' RTs (N=35):

The inflexion point of participants' fitted sigmoid functions were lower in the rough compared to the non-rough sound condition [$t(34) = -1.85, p = 0.037$, one-tailed, three participants were excluded due to bad fitting].

Discussion/Conclusion

- ① The Rough sound is perceived as more negatively-valenced and more arousing than the Non Rough sound
- ② The Rough sound starts interacting with tactile processing at a farther distance from the body compared to the Non rough sound

⇒ Roughness impacts the multisensory integration in relation to the body

⇒ Roughness could be an auditory attribute efficiently conveying a signal of danger to the central nervous system

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