

# Conditioned and social predictions of sound intensity and related aversiveness

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## Introduction

- Expectations and beliefs can exert powerful influence on human behaviour and perception, and even affect our physiology, as exemplified by the placebo effect.
- Priors can be established by different sources: by previous personal experience or associative learning, or from social interaction, such as the experience of others.
- Research on pain shows that conditioned and social expectations modify nociceptive processing, and this is mediated by different brain areas depending on the source of priors [1].
- This research aims to uncover whether expectations can alter the affective characteristics of auditory stimuli, and whether the underpinning neural mechanisms of social and conditioned expectations are different.

## Methods

- Behavioural and physiological responses (heart rate and skin conductance) were acquired from **44 participants** with normal hearing (14 males, age:  $23.9 \pm 4.25$ ; range: 19.12 – 39.73).
- Repeated measures ANOVAS were used to assess significance of behavioural and physiological data.
- Electrocorticography (ECoG) data was recorded from **2 epilepsy patients**. A whole brain temporal PCA during medium loudness tones was performed. Significance was assessed with permutation tests ( $n=500$ ).

## Experimental Design

- Auditory stimuli consisted of 3 seconds-long 1 kHz tones played at 3 different **loudness** levels (Fig 1):
  - Low** (82 dB)
  - Medium** (86 dB)
  - High** (90 dB)
- Sounds were preceded by 2 simultaneous visual cues:
  - A conditioned (**CS**) cue
  - A social (**SOC**) cue
- Each cue ‘predicted’ a tone high (**H**) or low (**L**) in loudness / aversiveness orthogonally.

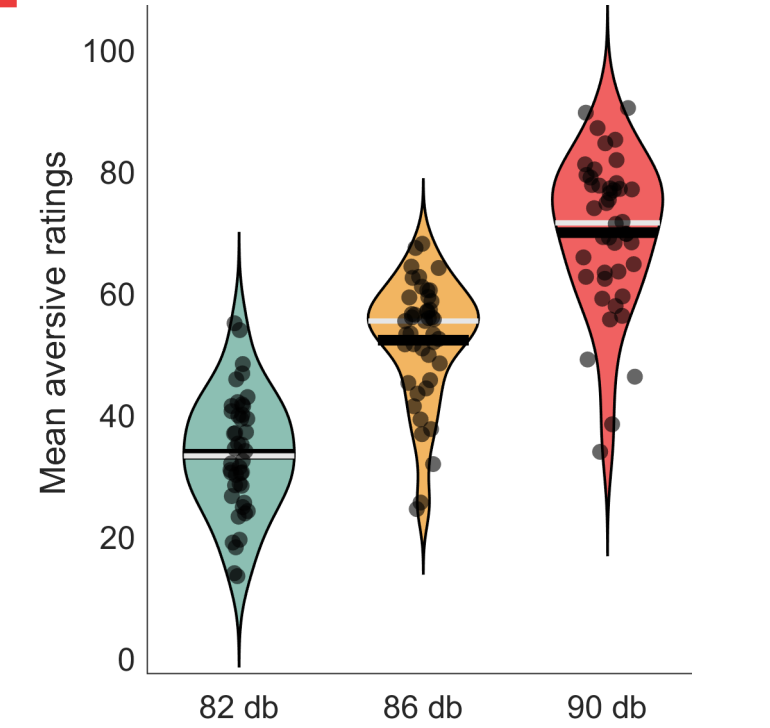


Fig 1. Aversive ratings by loudness ( $p < 0.001$ ).

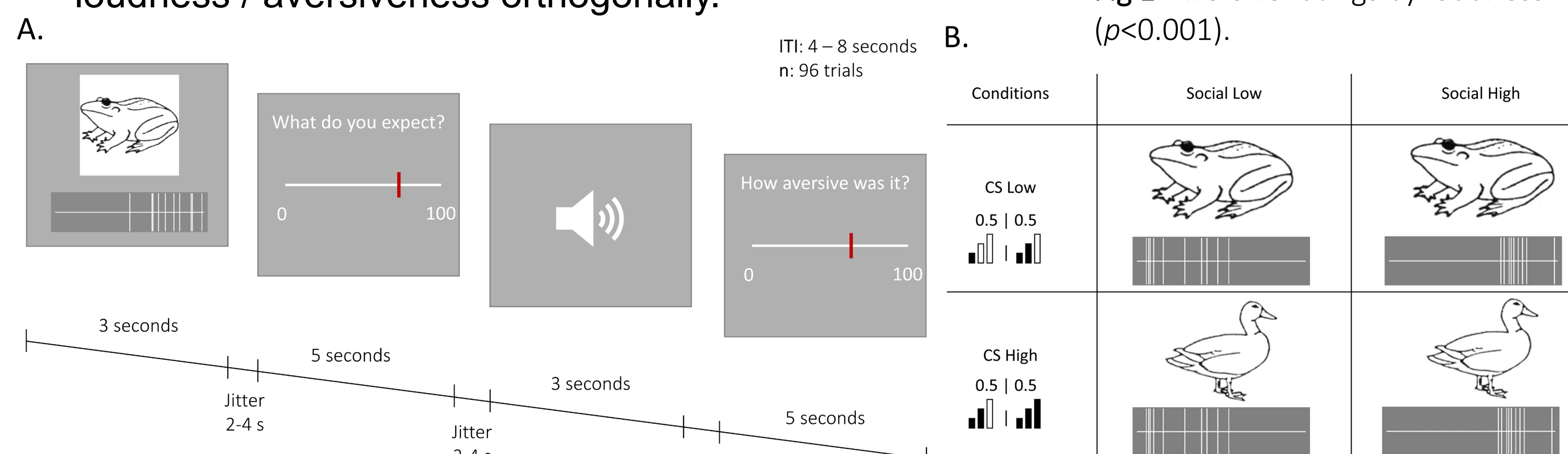


Fig 2. A. Experimental design. B. Conditions. CS cues were followed by either H or L tones half of the time and M the remaining half. SOC cues represented the aversiveness ratings of 10 ‘prior’ participants to the tone they were about to hear. These were invented data and bore no relationship to the loudness of the upcoming sound.

- Participants were asked how loud they **expected** the sound to be (0-100), and how **aversive** it was (0-100) before and after sound onset, respectively.

## Behavioural Results

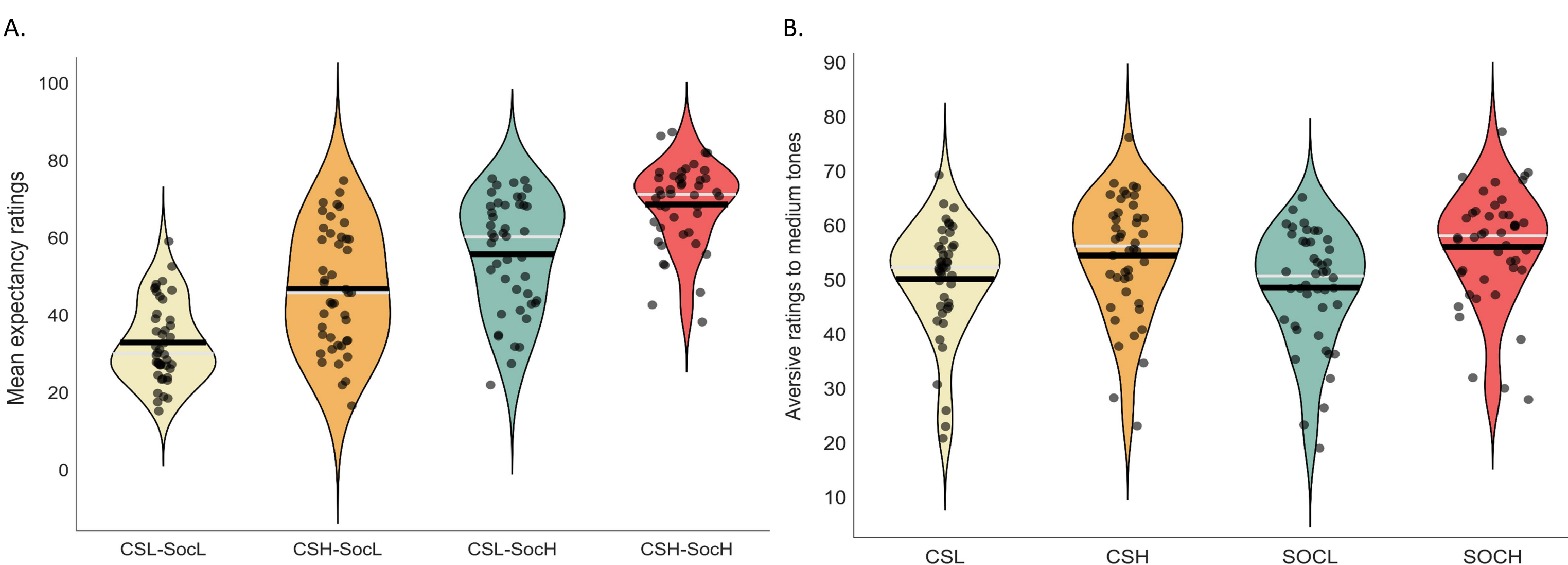


Fig 3. A. Expectancy ratings of loudness after each cue combination. There was a main effect of cue (CS:  $F(1,43) = 35.66$ ,  $p < 0.001$ ,  $\eta^2 = 0.453$ ; Soc:  $F(1,43) = 93.72$ ,  $p < 0.001$ ,  $\eta^2 = 0.685$ ) but no interaction ( $F(1,43) = 1.64$ ,  $p = 0.21$ ,  $\eta^2 = 0.037$ ). B. Aversive ratings to medium loudness according to preceding cue. There was a main effect of predicted intensity (H vs L:  $F(1,43) = 77.19$ ,  $p < 0.001$ ,  $\eta^2 = 0.64$ ) but not cue type (CS vs Soc:  $F(1,43) = 0.16$ ,  $p = 0.69$ ,  $\eta^2 = 0.004$ ).

## ECoG Results

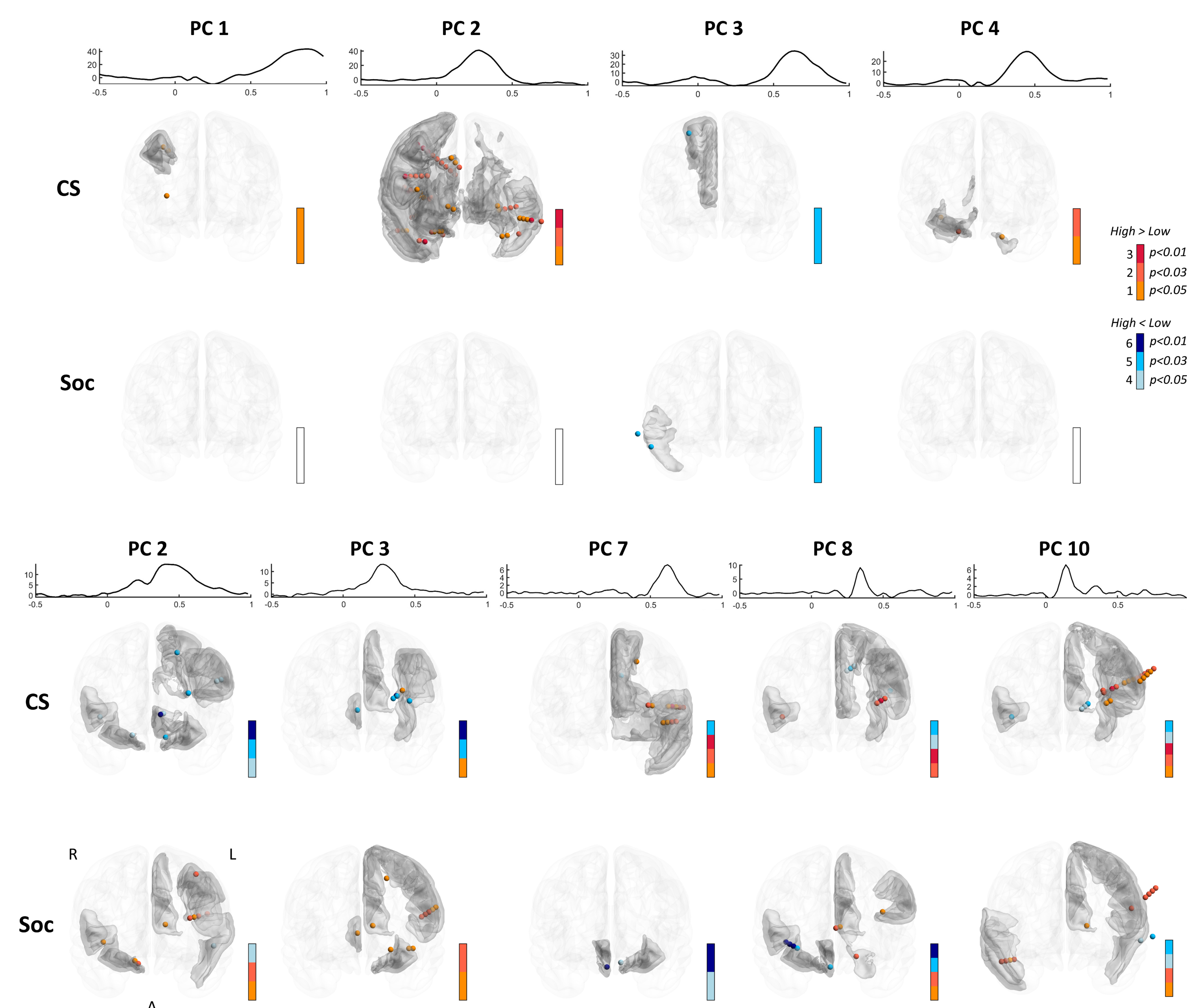


Fig 5. Whole brain temporal PCA of Patient 1 (A) and 2 (B). Statistical significance was assessed by permuting the type of trial (High vs Low) for conditions CS and SOC separately ( $n=500$ ).

## Physiological Results

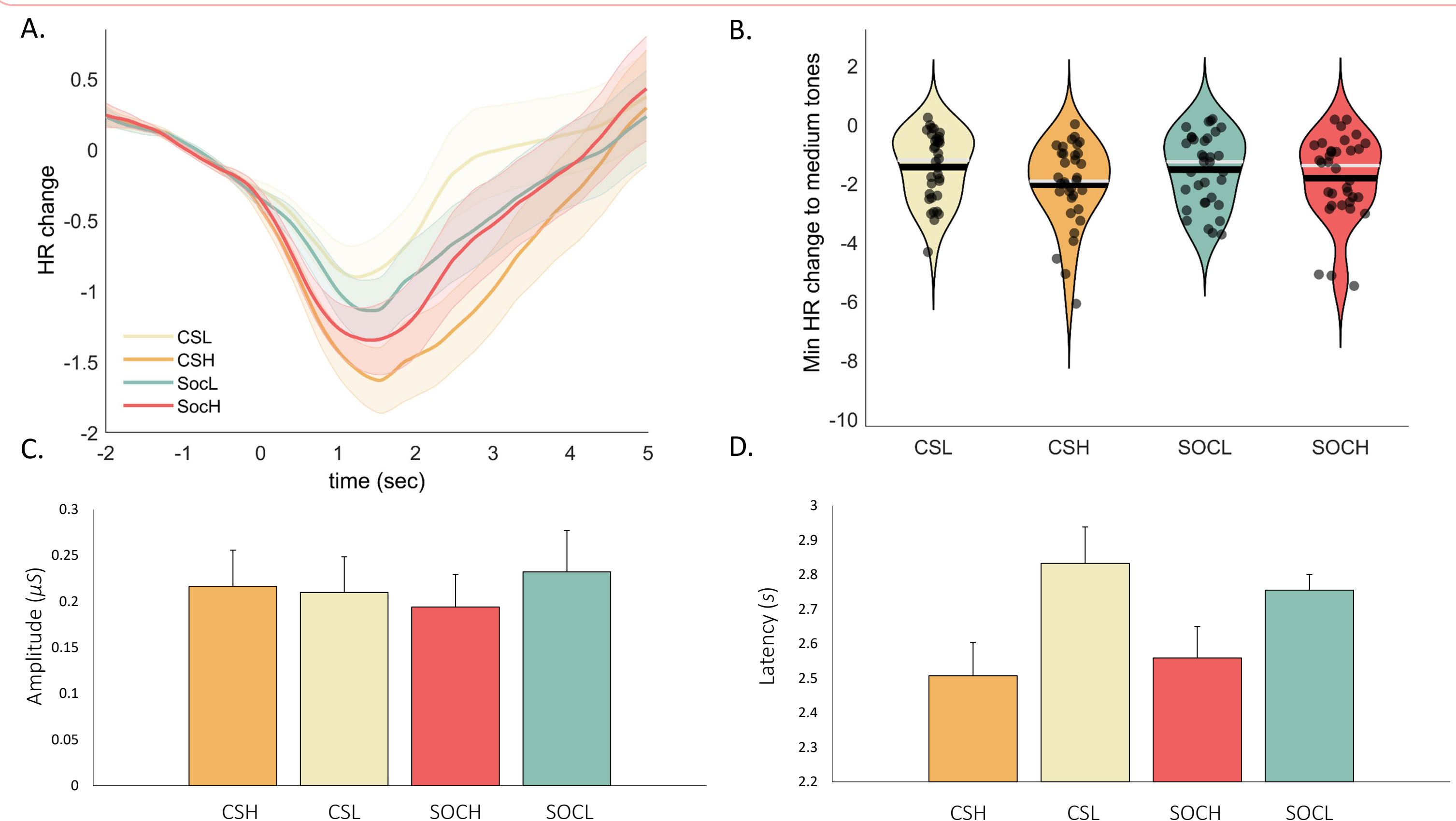


Fig 4. A. Time-course of heart rate (HR) change (bpm) compared to baseline time-locked to medium loudness tones according to preceding cue. B. HR deceleration (minimum change) during sound processing according to cue type. There was an effect of predicted intensity (H vs L:  $F(1,33) = 6.25$ ,  $p = 0.018$ ,  $\eta^2 = 0.16$ ), but not of cue type (CS vs Soc:  $F(1,33) = 2.74$ ,  $p = 0.11$ ,  $\eta^2 = 0.08$ ). C. Amplitude of skin conductance responses (SCR) to medium loudness tones according to cue ( $p > 0.05$ ). D. Latency of SCR according to cue (predicted intensity:  $F(1,25) = 13.28$ ,  $p = 0.001$ ,  $\eta^2 = 0.35$ ; cue type:  $F(1,25) = 0.22$ ,  $p = 0.64$ ,  $\eta^2 = 0.01$ ).

## Conclusions

- Here, we induced expectations of loudness and their related aversiveness using visual cues followed by tones of 3 loudness levels: Low, Medium, and High.
- Conditioned and Social cues both successfully generated expectations of loudness.
- The perceived aversiveness of tones with same loudness (Medium) was altered in the direction of expectations.
- This change in subjective aversiveness was accompanied by increased physiological arousal during sound perception: greater heart rate deceleration and faster SCRs.
- Intracranial recordings of epilepsy patients demonstrated neural responses to medium loudness tones were altered by expectations.
- Expectation effects were measured in a wide network of areas including **sensory areas**, such as primary auditory cortex, motor and visual cortices; the **limbic system**, such as basal ganglia nuclei, hippocampus, entorhinal cortex, and cingulate; **prefrontal cortex**, such as OFC, IFG, and SFG; parietal cortices and **insula**.
- Overall, our results show a role of expectations, whether conditioned or socially transmitted, in shaping the behavioural, physiological, and neural response to affective auditory stimuli.**