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Effects of cardiac cycle and respiration phase on trace eyeblink conditioning in elderly adults

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INTRODUCTION

Associative learning allows organisms to make predictions about their environment and adapt their behavior accordingly. Our recent research (Waselius et al., 2022) suggests that a certain phase of the cardiorespiratory rhythm (expiration-diastole) may be beneficial for learning trace eyeblink conditioning (TEBC) in healthy young adults. In this study, we investigated how the phases of breathing and heartbeat (i.e., expiration and diastole vs. inspiration and systole) impact associative learning in healthy elderly adults.

METHODS

We recruited 50 participants. The final sample consisted of 41 participants (9 males and 32 females), aged 70–83 years, with no diagnosed memory impairment. All subjects went trough TEBC while watching a silent nature film as depicted in Figure 1. During the session we recorded EEG, ECG, EMG from the eyelid, and respiration. After the TEBC session participants answered a short questionnaire regarding the content of the film and the TEBC task (Waselius et al., 2022). Last, the cognitive status of each participant was assessed with CERAD (Alenius et al., 2022). Data was analyzed with custom Python and Matlab scripts and statistical analyses were performed using SPSS (repeated measures analysis; between groups comparisons; correlations).

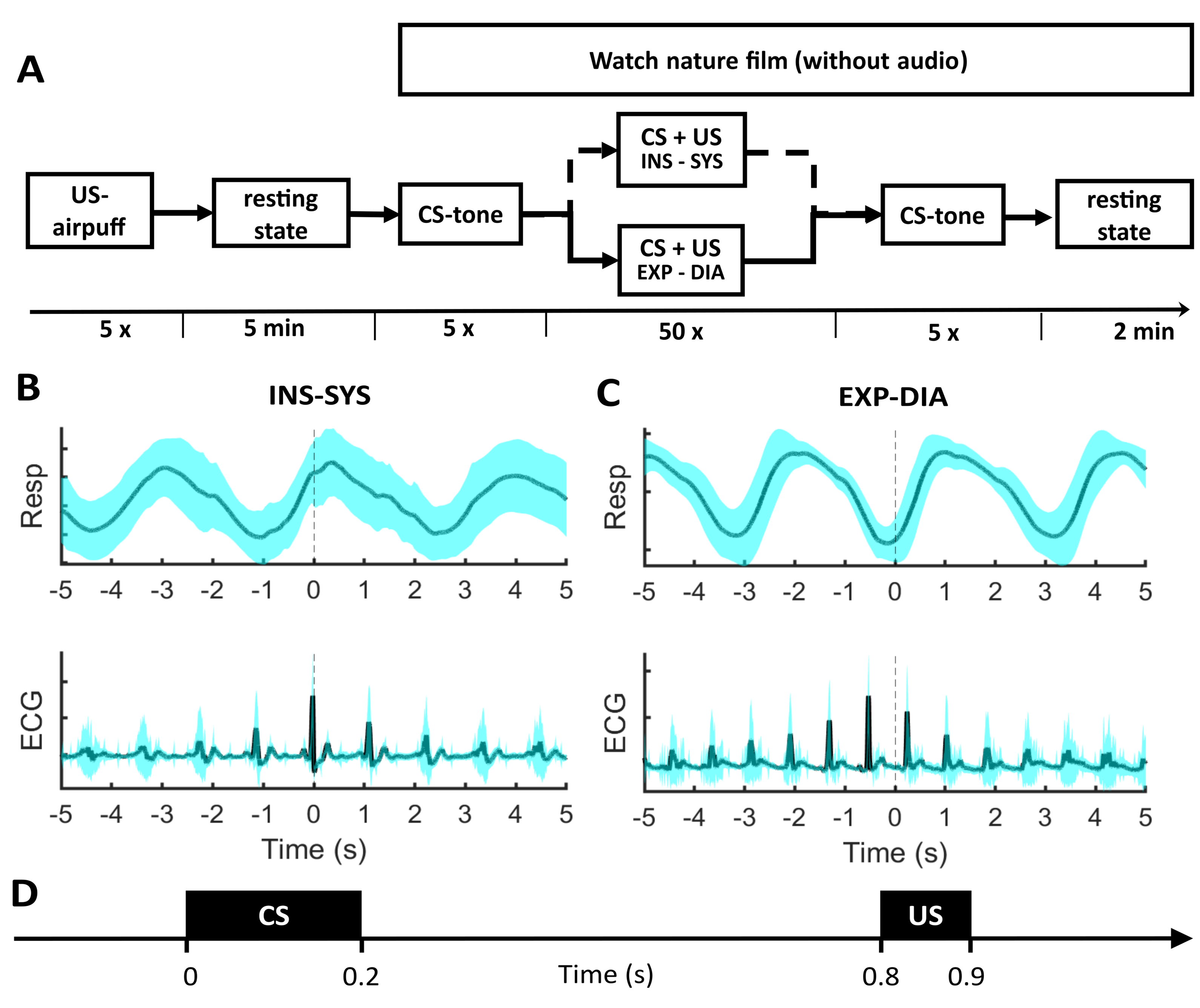

Figure 1. Schematic illustration of the experiment.
A) Participants were trained in classical trace eyeblink conditioning (TEBC), while watching a silent nature film. Abbreviations: US = unconditioned stimulus, CS = conditioned stimulus. Paired trials were presented either at B) systole during inspiration (INS-SYS) or at C) diastole during expiration (EXP-DIA). Cyan area in B and C represents standard deviation of 50 trials and the average is shown on top in black. Respiration (Resp) phase was measured using a stretch belt: lungs are full when the signal is at peak. Cardiac cycle phases were determined from the electroencephalogram (ECG). D) The 200-ms CS and the 100-ms US during a paired TEBC trial were separated by a 600-ms silent interval.

RESULTS

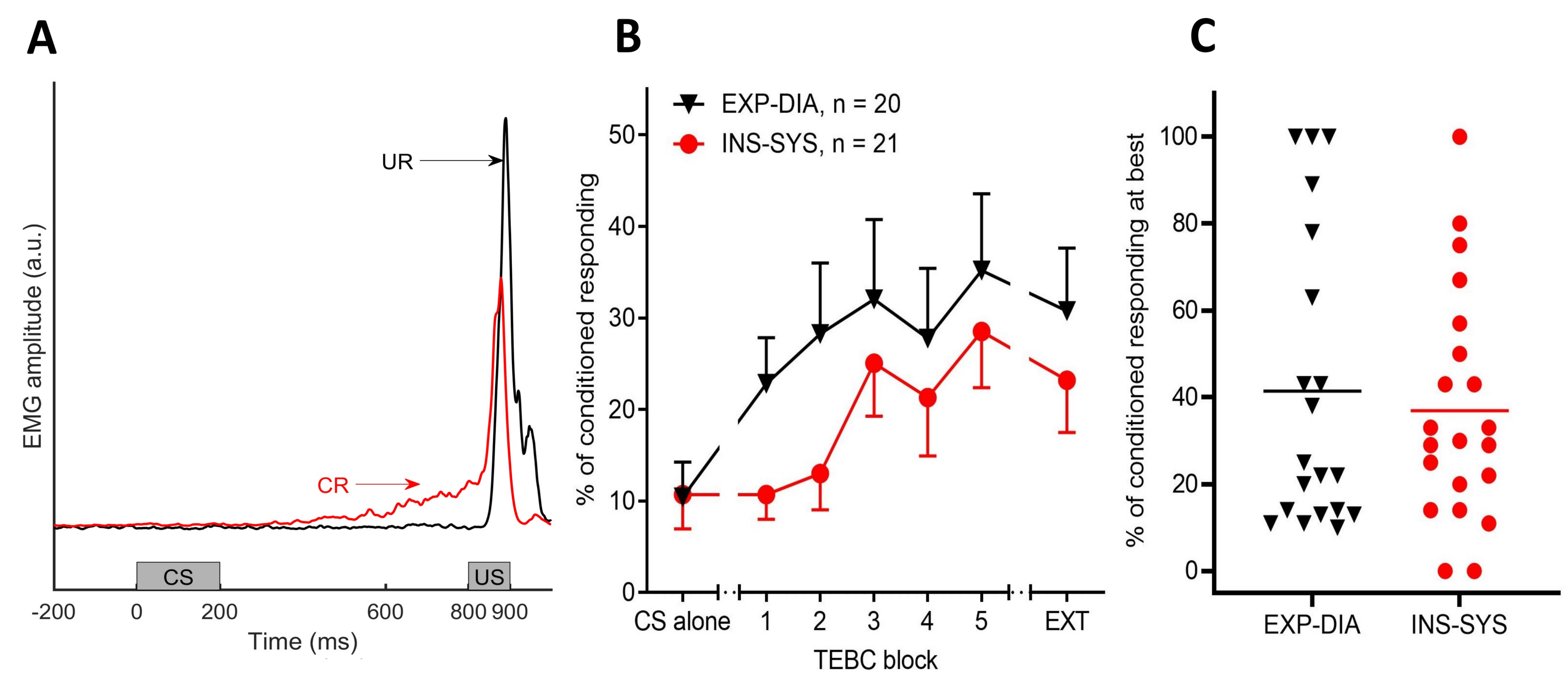

Figure 2. Learned responding (%) during TEBC did not differ in participants to whom the stimuli were presented at diastole during expiration (EXP-DIA) compared to participants to whom the stimuli were presented at systole during inspiration (INS-SYS).
A) Eye blinks were determined from EMG activity. A blink was considered an adaptive conditioned response (CR) if it started after the conditioned stimulus (CS) and shielded the eye from the airpuff-unconditioned stimulus (US). UR = unconditioned response. B) Both groups learned equally well. C) To evaluate optimal performance, we determined the highest percentage of CRs for each participant during a given 10-trial block towards the end of TEBC (blocks 3 to 5). There was no difference between groups in the final outcome of TEBC.

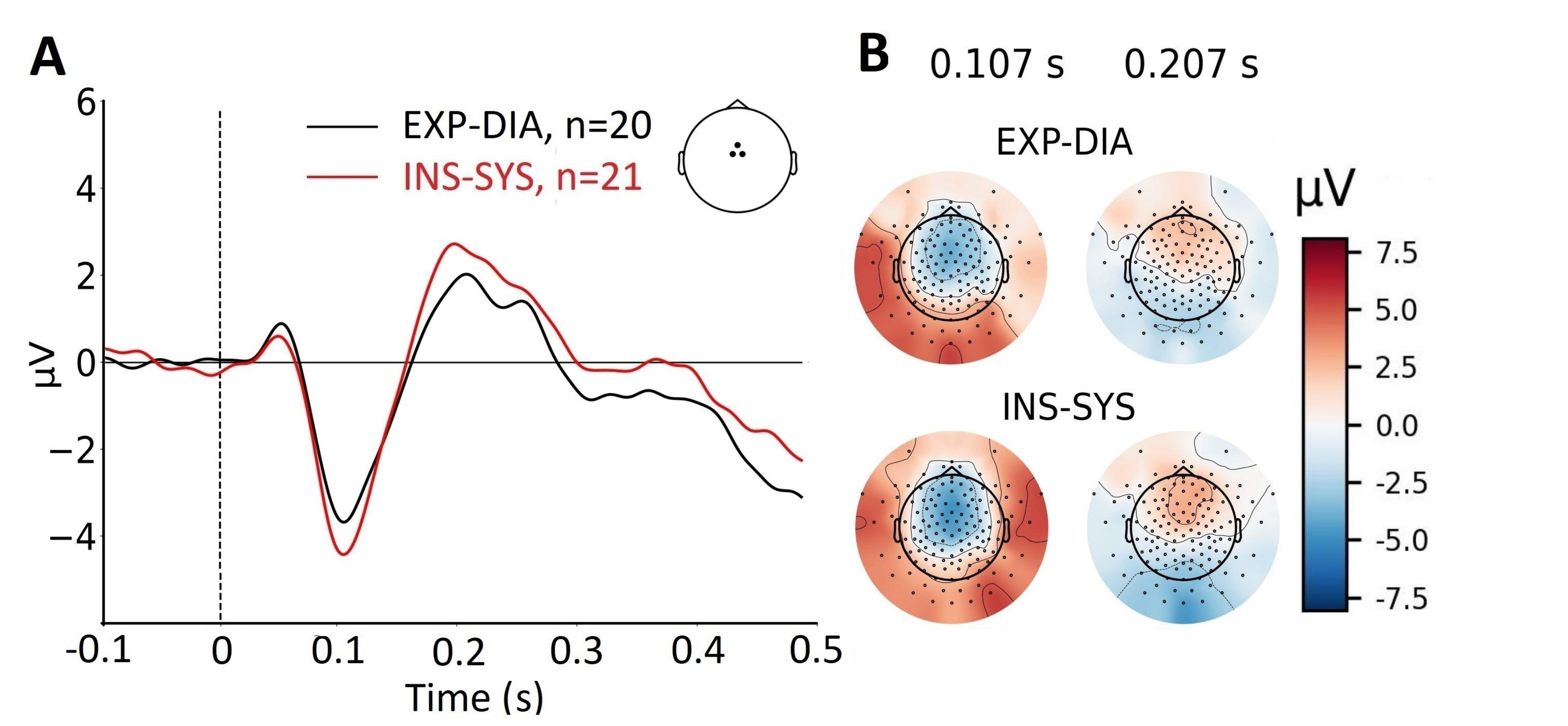

Figure 3. The tone-conditioned stimulus evoked a similar response in the brain of elderly participants regardless of whether it was presented starting at EXP-DIA or starting at INS-SYS.
A) The grand averaged ERP waveform in the frontocentral region (channels 6, 7, and 106) plotted separately for EXP-DIA and INS-SYS groups. B) Topographic maps illustrate the auditory N1 peak, occurring at 107 ms, and the auditory P2 peak, occurring at 207 ms, separately for both groups.

CONCLUSION

Elderly adults exhibited robust brain responses to the tone-CS and the number of motor conditioned responses increased across TEBC training. Interestingly, the timing of the CS in relation to the cardiorespiratory rhythm phase did not affect CS-evoked brain responses or acquisition of the conditioned eye blink. As a qualitative finding, both brain responses and conditioned eyeblinks were attenuated compared to those in young adults in our previous study (Waselius et al., 2022). These findings highlight the challenges faced by elderly adults in adapting their behaviour to environmental changes.

REFERENCES

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