Drivers of the Dive Response in Pinnipeds

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Background

Long and deep dives in marine mammals are enabled by high mass-specific oxygen stores[1] and the dive response reducing oxygen consumption during dives in concert with increased peripheral vasoconstriction and a lowered heart rate (bradycardia)[2,3]. Diving heart rates of pinnipeds are highly variable and modulated by many factors, such as pressure[4], swimming activity[5], and even cognitive control[6]. However, the individual effects of each of these on heart rate is poorly understood due to the difficulty of teasing them apart in diving pinnipeds. In contrast, studies on humans show bradycardia during facial stimulation by cold water[7] even when still breathing air[8], whereas apnoea alone only result in a weak reduction of the heart rate[9]. Therefore, we examined the effect of apnea and external sensory inputs as autonomic drivers of the diving bradycardia in pinnipeds.

Hypotheses

1) Water stimulation of facial receptors would, as is the case for terrestrial mammals, enhance the dive response.
2) Increasing the number of facial receptors stimulated (larger area of the face) will lead to a more intense bradycardia.
3) Cold water would elicit a more pronounced bradycardia than warm water.

Methods

Trained animals
- Three harbor seals (Naja, Svante & Sprouts)
- One California sea lion (Ronan)

Enclosure
Fjord and Bælt, Kerteminde, Denmark
Long Marine Lab, Santa Cruz, Ca, USA

Instantaneous heart rate (f_H) acquisition
- Custom-built ECG electrode plate built into slightly sloping ramp
- Animals on land, on ramp while measuring ECG signal

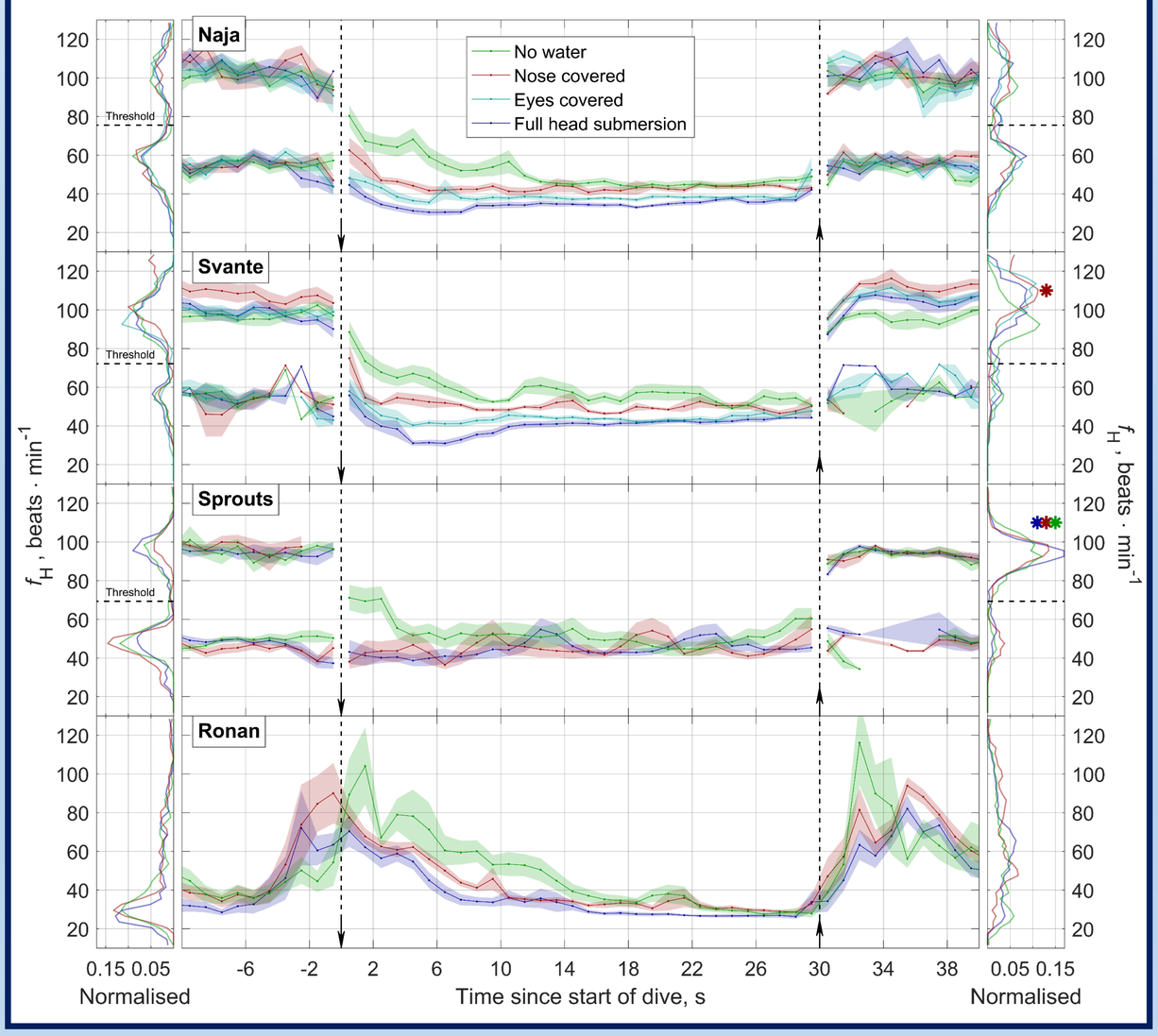
Experiments

Degree of facial submersion
- Animals trained to lower head into tub with different amounts of water
- 30s submersion (15 trials at each step)

Temperature effect
- 30s full head submersion into tub
- Two tubs; one with 0-5°C water, one with 30-35°C water (15 trials at each temp.)

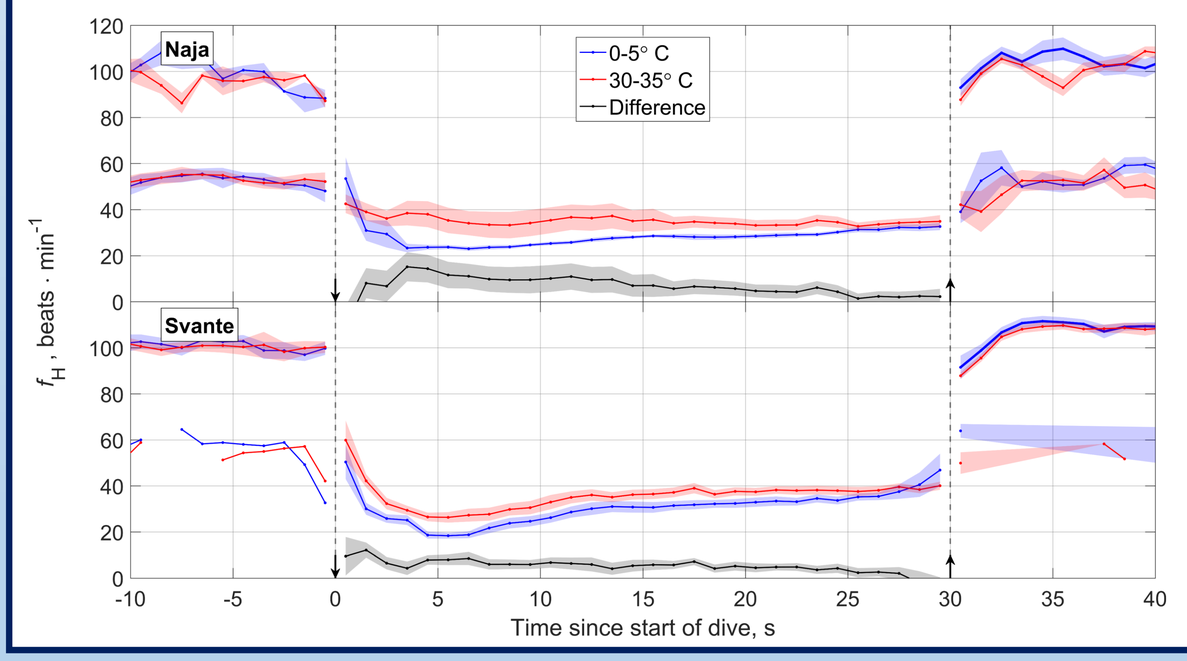
Degree of facial submersion

30-second submersion in different levels of water stimulating different amount of facial receptors. **The larger the facial area stimulated the deeper the brady-cardia.** The greatest difference in submersion bradycardia was present within the initial 10 seconds of the submersion.



Temperature effect

30-seconds full head submersion in cold or warm water. **Cold water resulted in a more pronounced brady-cardia than warm water,** with the greatest difference at the start of the full head submersion.



Conclusion

The experimental setup allowed for control of the different drivers of the dive response and isolation of the effect by apnoea and facial stimulation by water. The results show **strengthened dive response with increasing face immersion** and **colder water**. However, **pronounced bradycardia is present during apnoea alone**, contrary to the human dive response, showing apnoea to be a primary driver of the dive response in pinnipeds.

Marine Bioacoustics Lab

Marinebioacoustics.com

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Animal ethics

All data collected at the Pinniped Cognition and Sensory Systems Laboratory at the Long Marine Laboratory were collected under authorization from the National Marine Fishery Services of the United States under Marine Mammal Research Permit 18902. Furthermore, data were collected under the oversight of the Institutional Animal Care and Use Committee of the University of California, Santa Cruz.