Eye movement responses to caloric vestibular irrigations reveal the contribution of voluntary processes to autonomic reflexes

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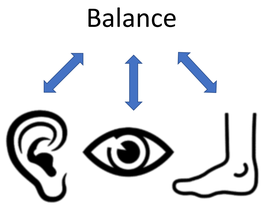
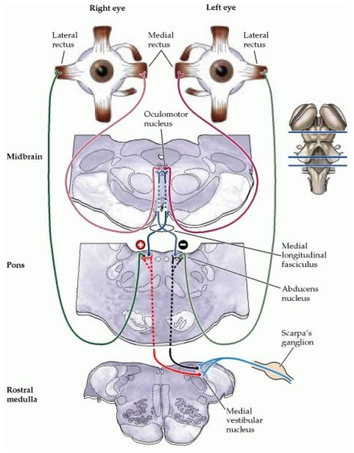
Introduction

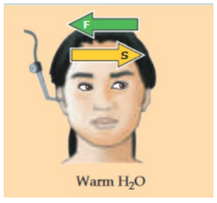
- **Autonomic reflexes** are unvoluntary responses that can be top-down regulated
- **Question:** Can autonomic reflexes inform us about higher-cognitive processes?
- **Goal:** To characterize the influence of voluntary processes on behavioral and physiological correlates of an autonomic reflex adaptation

Methods

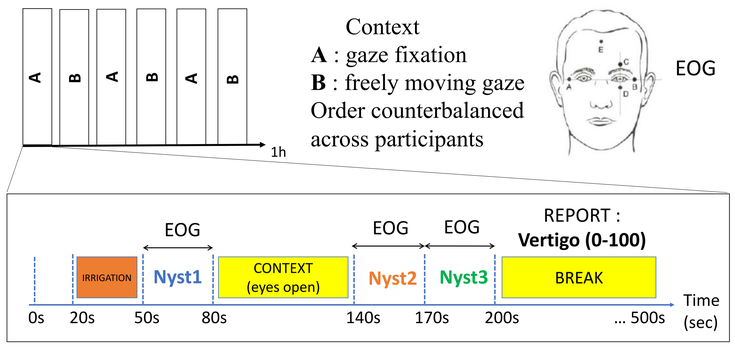
- **Paradigm:**
  - Caloric irrigation of the external ear canal (hot water: 44°C)
  - Stimulation of the vestibulo-ocular reflex[1]
  - Induction of vertigo and eye movement responses (nystagmus)





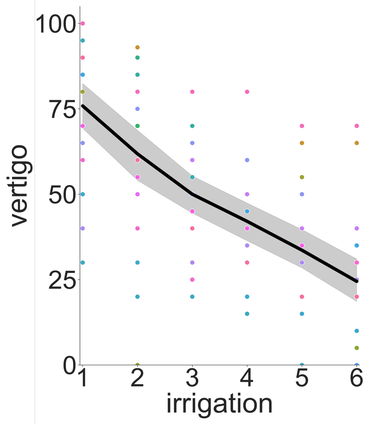


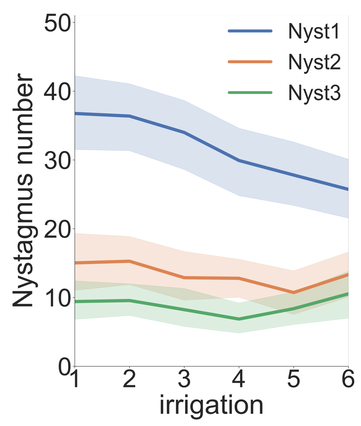
- **Protocol:**
  - 26 typical adults (16 F, Age: 18-35y) without hearing nor balance deficits
  - 6 repetitive irrigations with alternating context (AB scheme)
  - Electro-oculogram (EOG) and vertigo rating (0-100) after each irrigation



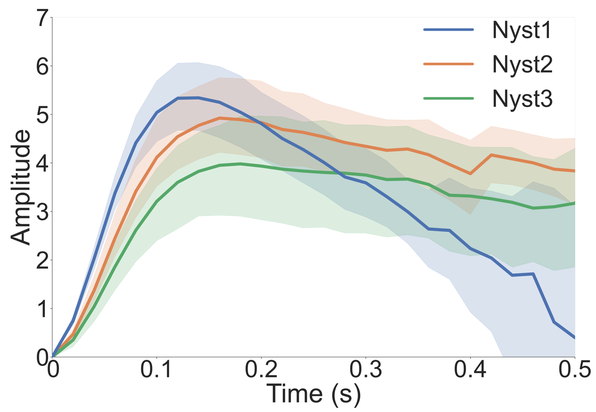
Results

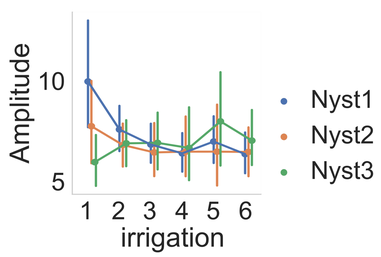
- **Behavioral and physiological evidence of response adaptation:**
  - Vertigo decreases over repetitions (trend-test, $p<0.001$)
  - Nystagmus number decreases over time and repetitions (trend-tests, $p<0.001$)
  - Nystagmus number partially explains vertigo (model comparison, $p=0.003$)

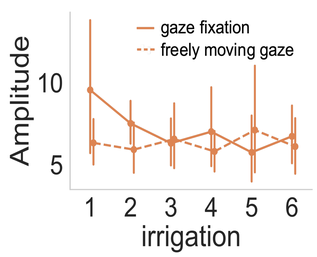




- **Influence of voluntary processes on response adaptation:**
  - No effect of context on vertigo feeling (repeated measures ANOVA: $p>0.05$)
  - Amplitude of nystagmus depends on context and repetition (ANOVA: $p=0.03$)
  - Gaze fixation increases amplitude of nystagmus following the first irrigation (ANOVA for Nyst2: fixation: $p=0.013$, fixation x irrigation : $p=0.036$)

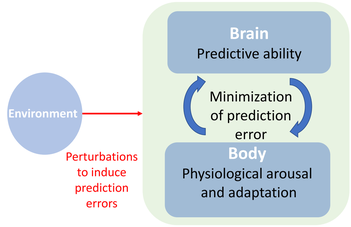


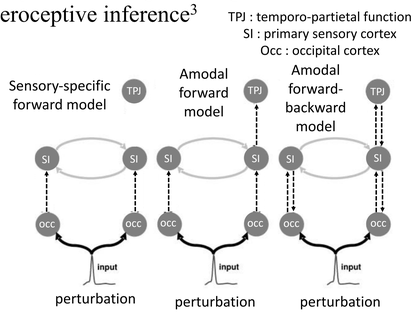




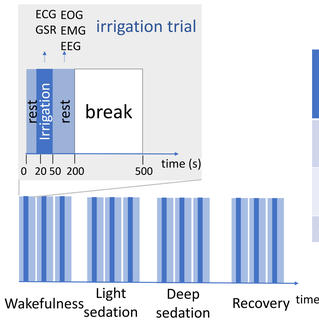
Discussion

- **Active interoceptive inference**
  - Brain-body interaction explains the subjective feeling of vertigo[2]
  - Adaptation as a result from active interoceptive inference[3]
  - Dynamic causal modeling approach[4]





- **Test under anaesthesia (follow-up):**
  - Propofol sedation (light and deep)
  - Multichannel recordings : brain and body electrophysiology
  - Hypotheses on the influence of conscious states on bodily awareness



Type of consciousness	Presence of adaptation	Dynamic causal model	State of consciousness
Connected consciousness	Yes	amodal	wakefulness
Disconnected consciousness	Yes	Modal	Light sedation
unconsciousness	No	modal	Deep sedation

Conclusions

- Repetitive caloric vestibular irrigation reveal:
  - Multisensory integration within the balance system
  - Behavioral and physiological adaptation
  - Bidirectional interaction between bottom-up and top-down processes
- Autonomic reflexes can be used as a window into higher-order processes by:
  - investigating neural correlates of response adaptation
  - differentiating adaptation at different hierarchical levels
  - studying alterations of higher-order process under propofol sedation

References

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Data and code available on OSF and Github and Poster available on Orbid