Translations do affect vestibular stabilization performance

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Can vestibular translatory cues enhance self-stabilization?

1 Introduction

We investigated the usability of vestibular translatory motion cues in self stabilization. Six blindfolded observers were asked to control the pitch or roll axis (see Fig. 1) of a Stewart motion platform (see Fig. 2) which followed the movements of a virtual inverse pendulum. We varied the height of the pendulum's turning axis with respect to the observer's head (see Fig. 3). Shifting the turning axis along the body axis leaves the vestibular rotational cues identical while changing only the translatory component of the motion.

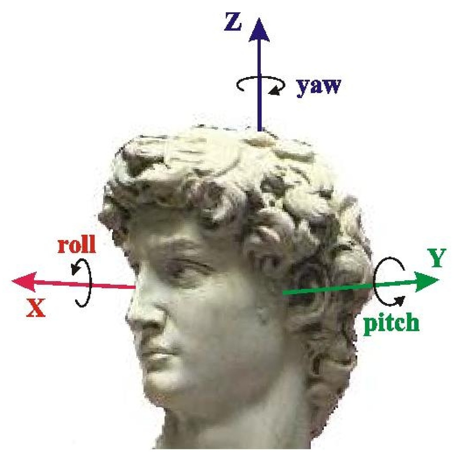


Fig. 1: What is roll and pitch?

Subjects stabilized themselves on a simulated inverse pendulum.

2 Hypotheses

I) If the translatory components do not affect stabilization, performance should be equal for all conditions.

II) If translation does affect stabilization, then increasing the distance between the head and the turning axis should systematically alter performance.

III) In posture control, humans always rotate (tilt) around points below the head and therefore those conditions should result in better performance.

Fig. 2: Roll on the motion platform.

We changed the relative height of the subject with respect to the turn axis of the pendulum.

All rotational cues remained identical but the translatory component of the movement is changed.

3 Methods

The experimental paradigm

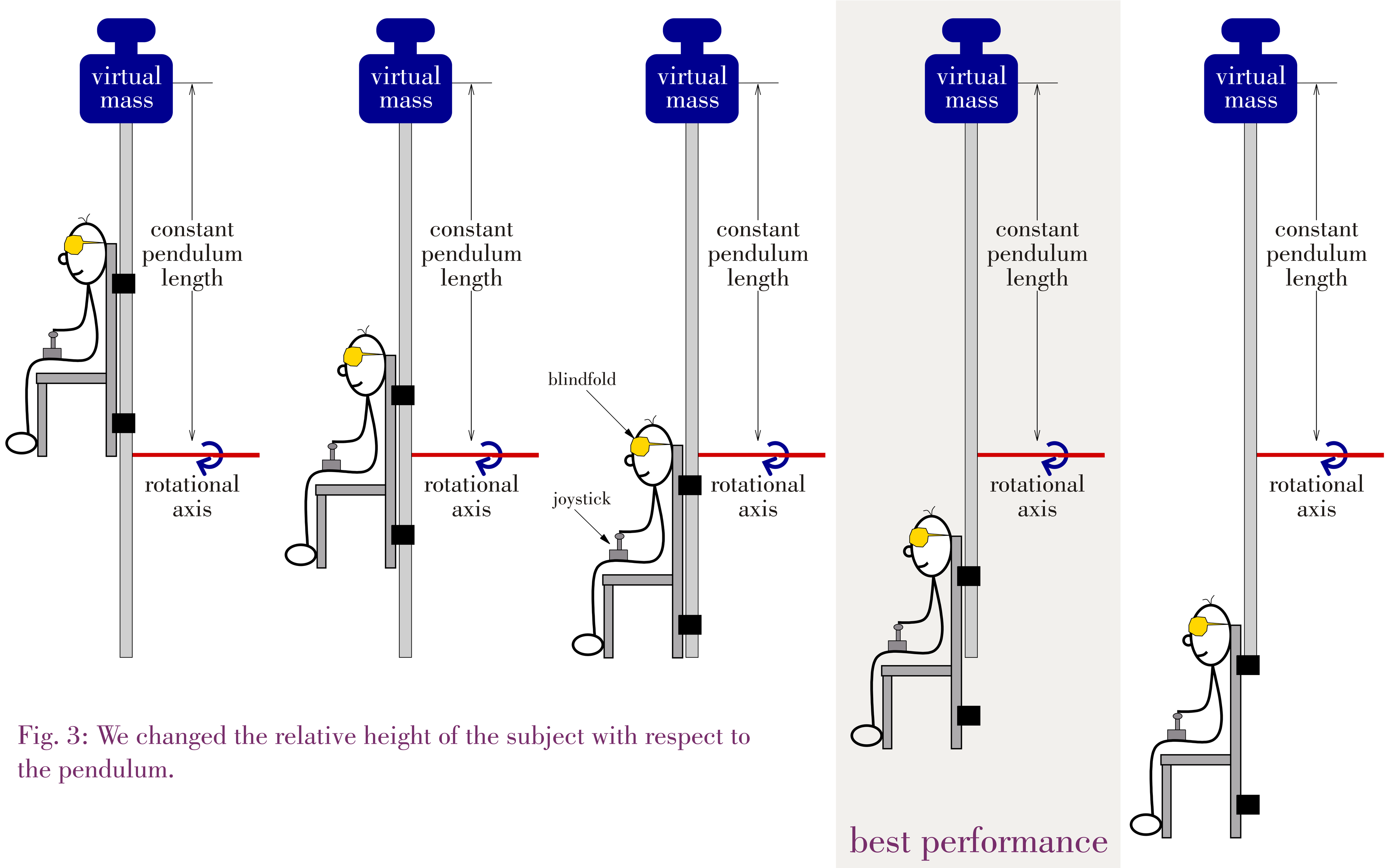


Fig. 3: We changed the relative height of the subject with respect to the pendulum.

Performance was measured by means of absolute position or velocity and their respective variance.

Subjects controlled the pendulum with a virtual force proportional to the deflection of a joystick (acceleration based control). Five different turning axis heights with respect to the head (h=0.0m, ±0.6m, and ±1.2m) were tested in trials that lasted 60 seconds each. The experiment consisted of 12 repetitions of all heights (performed in three blocks with four repetitions each). Observers typically reached a stable performance during the second block (i.e., after about 30 minutes of training). To exclude learning artifacts, we limited the analyses to the last four repetitions of all heights.

Subjects performance was best when the rotational axis was 60cm above their head.

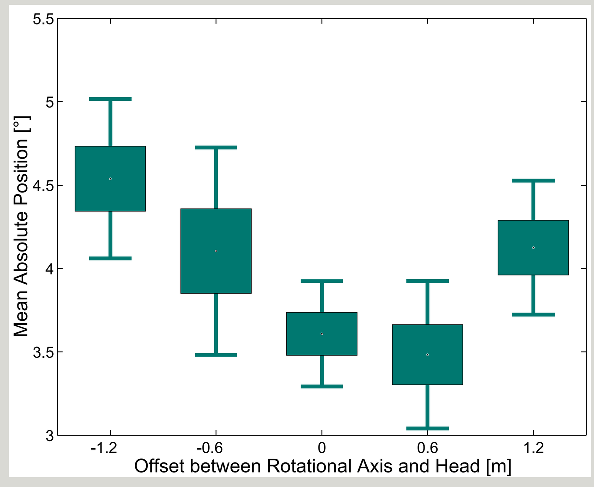
4 Results

We measured performance across the last four repetitions by means of absolute error and variability of position and velocity (see Figures on the right; the whiskers depict one standard deviation of the mean and the boxes indicate the standard error). Surprisingly, the final performance was best for the condition where the turning axis was 0.6m above the head. Also the amount of steering (= subject controlled accelerations) as well as the accumulated time of boundary collision reached the minimum at this condition. Performance decreased with increasing distance from this optimum. Therefore, none of our hypotheses were confirmed.

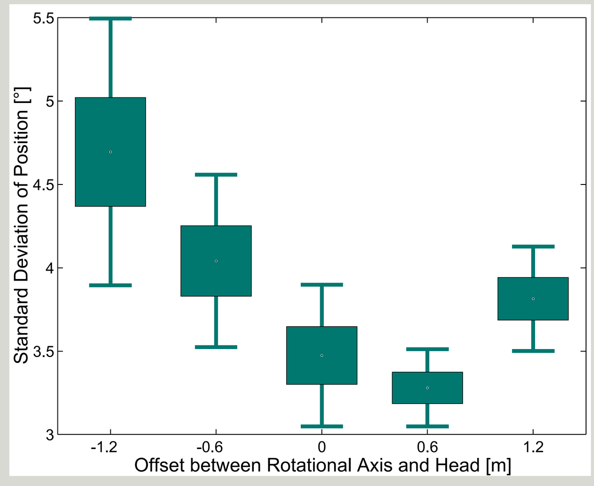
5 Conclusions

These results can help to design better helicopter simulators and optimize simulator training. Speculations about evolutionary explanations of our results (imagine swinging monkeys) await further investigation.

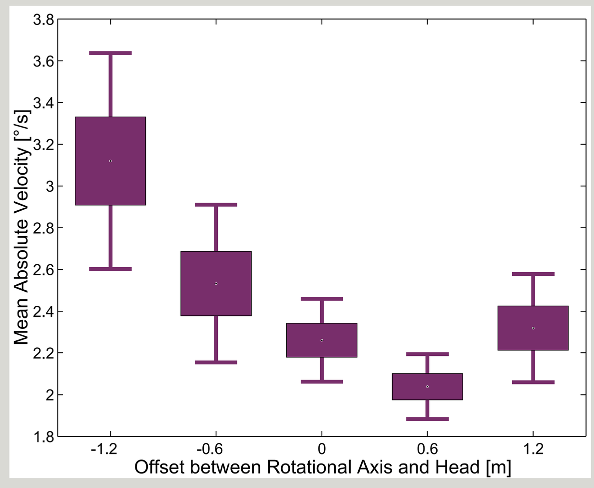
Absolute position



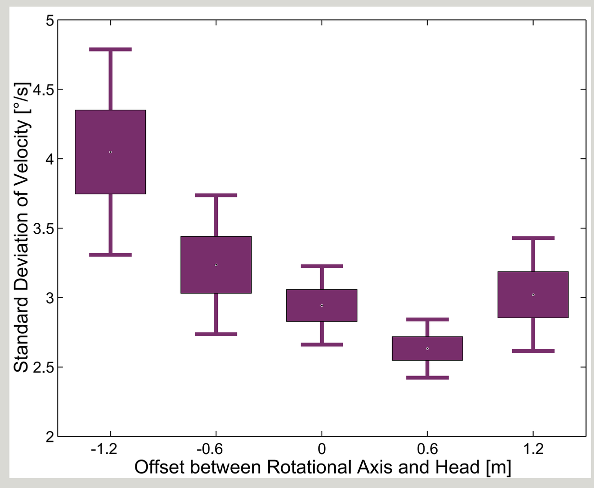
Standard deviation of position



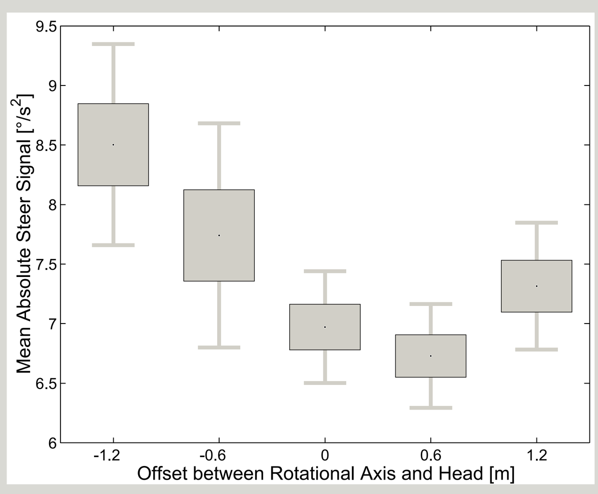
Absolute velocity



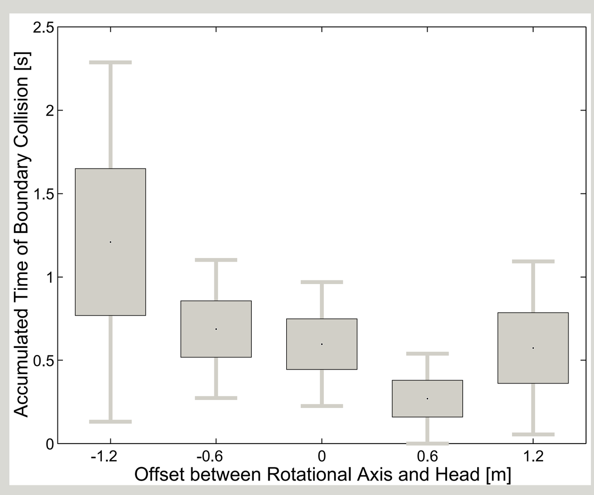
Standard deviation of velocity

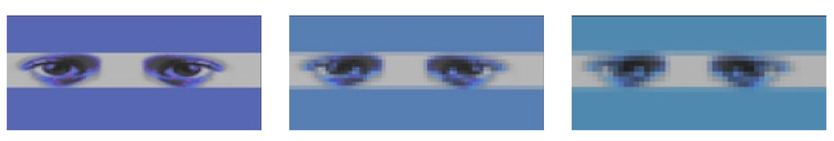


Absolute accelerations



Time of boundary collisions





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