Visual information and compensatory head rotations during postural stabilization

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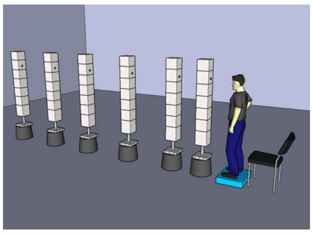
Introduction

The ability to correctly direct and maintain one's body position is central to the success of many actions. Many of the mechanisms responsible for this, including a wide variety of head-orientation adjustments, are reflexive or automatic. This study investigated how human observers use visual information to stabilize posture, with a focus on the influence of fixation distance and the consequent changes in head angle and position.

Experiment 1

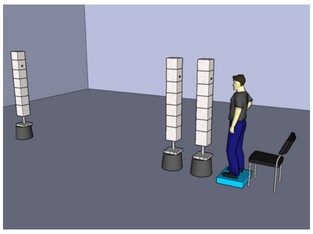


Experimental setup with 6 different positions of the fixation object.

Eight participants were required to stand as still and stable as possible on a soft foam balance pad while fixating a small target at eye-height on a dimly lit lamp. The room was completely darkened such that no other visual information was available. The lamp was placed at either 0.4m, 1.16m, 2.33m, 3.5m, 4.66m or 5.82m from the observer.

Head position and orientation were measured at 100 Hz using a Vicon™ tracking system. Participants wore a helmet with reflecting markers. Each trial lasted 40 s. A break of 30 s, during which participants were seated, occurred after each trial. Room lights were switched on during the breaks in order to prevent complete dark adaptation.

Experiment 2



Experimental setup with 3 different positions of the fixation object.

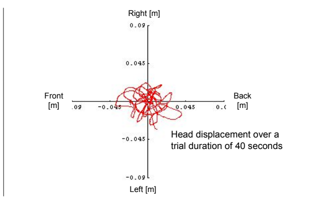
To determine whether the effect was based on physically presented or mentally represented distance, a second experiment with twelve participants and the following visual conditions was conducted:

- **eyes open (EO)**
- **eyes open in darkness (EOD)**
- **eyes closed (EC)**

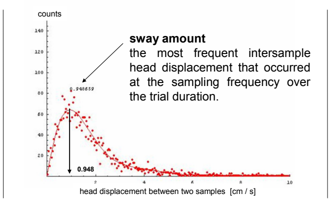
The fixation lamp was placed at either 0.4m, 2.33m or 5.82m. In the EC and EOD conditions, participants were instructed to imagine, as accurately as possible, the location of the fixation lamp.

Data analysis

To compensate for inaccuracies based on a non-constant sample frequency in the Vicon system, the data were down-sampled to 45Hz. Postural instability was calculated by quantifying the most frequent sway velocity (intersample displacement) that occurred at the sampling frequency. This measure was found to be more robust than other measures, such as sway trajectory length.

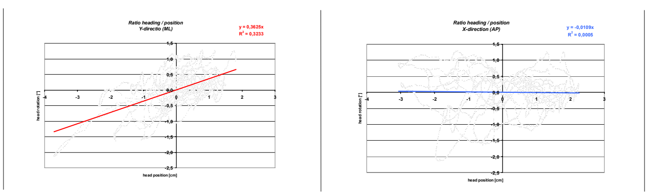


Typical sway trajectory of one subject during one trial.



Intersample displacement histogram of one subject during one trial.

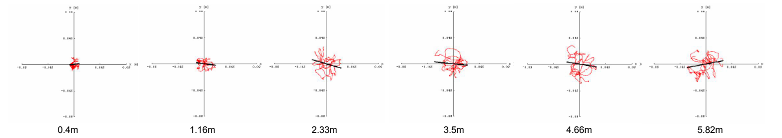
To quantify the correlation between head orientation angle (yaw) and head position, the slope of a linear regression between the two was calculated. Separate regressions were calculated for head position along the mid-lateral plane (left-right) and along the anterior-posterior plane (front-back).



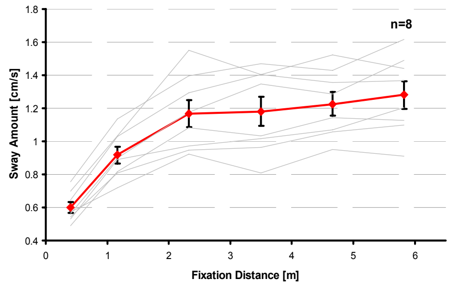
Typical correlation between head rotation angle and head position of one subject during one trial.

Results | head displacement

Results showed for both experiments that postural instability significantly increased with increasing fixation distance.



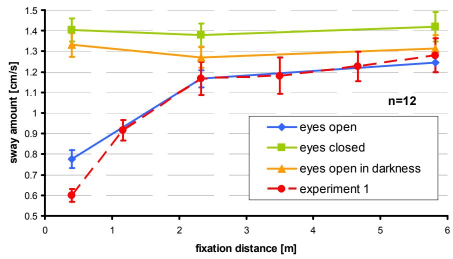
Raw data of single trials of one subject for all visual conditions



Amount of sway as a function of fixation distance. Individual subject and average data.

Experiment 1:

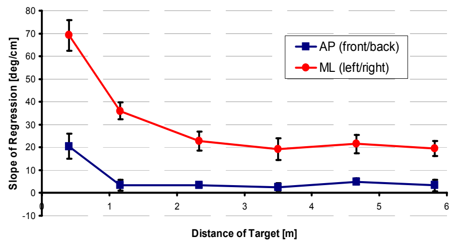
At 0.4m, the average sway velocity across 8 participants was 0.6 cm/s. This value increased to 1.3 cm/s at 5.82m. The increase of postural instability with increases in fixation distance reached a plateau at about 2.5m.



Experiment 2:

Results of a repeated-measures ANOVA showed significant main effects of distance [$F(2,22)=9.41$, $p<.005$] and visual condition [$F(2,22)=121.6$, $p<.001$]. Posture was significantly more stable in the EOD than in the EC condition [$F(1,11)=19.01$, $p<.005$].

Results | head rotation

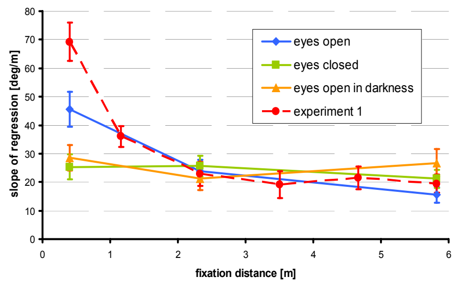


Correlation between head orientation angle and head position for AP and ML plane

Experiment 1:

A positive correlation between head orientation angle and head position in the mid-lateral plane was found. This means that during lateral postural sway, the head makes systematic compensatory rotations along the yaw-axis.

The correlation significantly decreased with increasing fixation distance and reached a plateau at about 2.5m. No correlation between head orientation angle and head position in the anterior-posterior plane was found.



Correlation between head orientation angle and head position. ML plane only.

Experiment 2:

For the compensatory head rotations, a similar result as in Experiment 1 was obtained for the EO condition. While there was also a correlation between head angle and position for both the EC and EOD conditions, this correlation did not vary as a function of imagined fixation distance.

Discussion and conclusions

Our results confirmed that postural stabilization is dependent on the distance to the fixation target. At about 2.5m, stabilization reached a plateau. Interestingly, systematic lateral head rotations were observed, and the correlation between head rotation and lateral position reached a plateau at about 2.5m. Critically, this correlation was also found without immediate visual input. This latter finding is reminiscent of other, automatic, head orientation reflexes.

Outlook

Further experiments will examine the effect of visual information as well as eye and head movements on human postural stabilization in more detail.

Poster presented at TWK 2007