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Perceiving and controlling simulated ego-rotations from optic flow: Influence of field of view (FOV) and display devices on ego-motion perception

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• Introduction

Goal: To disentangle the specific influences of different display devices and FOV on spatial perception

We investigated humans' ability to control simulated ego-rotations from optic flow. In general, the literature suggests that visual stimuli alone are insufficient for accurate spatial orientation when rotations of the observer are involved. However, studies so far have confounded different display devices and FOVs, and the data are highly inconsistent.

The present study aims to disentangle the influence of display devices and FOV on the ability to control simulated ego-rotations solely from visual information.

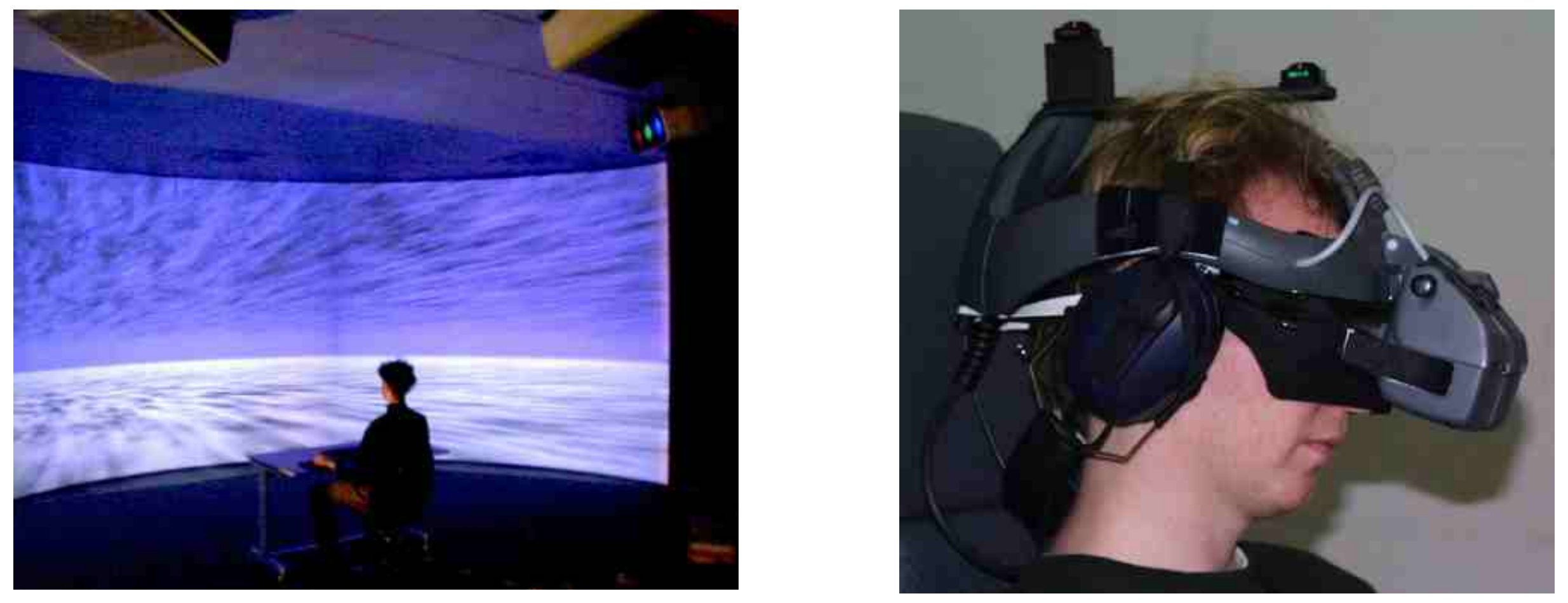

Figure 1: 180° half-cylindrical projection screen and HMD (FOV 40°×30°)

• Methods

Participants performed simulated turns under three different visualization conditions.

18 participants performed visually simulated ego-rotations in a within-subject repeated-measures design. Five turn angles (45° to 225°, steps of 45°) were crossed against four turning velocities (20, 27, 34, and 42°/s) and three visualization conditions (projection screen: FOV 86°×64°, HMD: 40°×30°, blinders: 40°×30°). The blinders restricted the FOV on the screen to the same FOV that was visible on the HMD. To provide only optic flow information without any landmarks, a "star field" of limited lifetime dots (dot lifetime 650 ms) on a dark background was used. Target angles were instructed via headphones, e.g. "Turn 90° to the left", and participants used a joystick to control the simulated turns. No training or feedback was provided at any stage of the experiment.

Figure 2: Experimental visualization conditions. Left: projection screen (FOV 86°×64°), middle: blinders (40°×30°), right: HMD (FOV 40°×30°). Subjects performed visually simulated rotations watching a "star field" of limited lifetime dots on a dark background.

• Results & Discussion

Generally, all target angles were undershot.

Performance was best with the full view on the screen and worst with the HMD.

Unexpectedly, FOV alone did not affect performance on the projection screen.

The size of FOV on the HMD was largely overestimated.

Generally, all target angles were undershot (see Fig. 3). For turn error as the dependent measure, a 3 (visualization conditions) × 5 (target angles) × 4 (velocities) × 2 (turn directions) repeated-measures ANOVA showed the following results: The effect of visualization condition was significant, as well as target angle. The presentation order of the three conditions had no significant effect (see Table 1). Bonferroni-corrected post-hoc tests revealed significant differences between the full screen and the HMD (p<0.001), and also between HMD and blinders (p<0.01), but not between screen and blinders (p=0.407). Thus, FOV did not affect performance on the projection screen. The interaction between visualization condition and target angle was also significant (see Fig. 3).

Mean subjective ratings about task difficulty were highest for the blinders (3.7 on a 5-point Likert-scale), as opposed to values of 2.7 for the screen and 2.8 for the HMD (see Fig. 4, left). This is remarkable because performance with the blinders was much superior to the HMD and did not differ significantly from the screen with full FOV.

It is worthwhile mentioning that in a post-test interview, the FOV of the HMD was estimated more than twice as large on average than the actual FOV (see Fig. 4, right). Participants also reported that the dots appeared to be farther away in the HMD than on the screen, even though dot size in terms of visual angle was equated for the two conditions. The largely overestimated size of the FOV in the HMD and the altered apparent distance to the stars seem to have contributed to the substantial performance deterioration (see HMD-data in Fig. 3 and 4).

• Conclusions & Outlook

Display devices were more crucial for turning performance than FOV.

One needs to be cautious when using HMDs to investigate basic perceptual processes.

The two main findings of the present study are:

First, display devices affected the control of visually simulated ego-rotations differentially.

Second, the FOV unexpectedly did not affect performance on the projection screen.

In line with the literature, large undershooting of intended turn angles was observed for the HMD. The bad performance with the HMD and the fact that the FOV on the HMD was largely overestimated indicate that one has to be cautious when using HMDs to investigate basic perceptual processes.

Comparing the results with the Riecke et al. (2002) study, it is notable that performance with the 86°×64° screen was inferior to the 180° half-cylindrical screen, where nearly perfect turning performance was found (see Fig.1 (left) and Fig. 2). Taken together, these results show that further systematic research is needed to understand the parameters that influence spatial perception in Virtual Reality (VR) applications, given that VR technology is already being used as a standard research tool for studies in perception and psychophysics. Follow-up studies will specifically investigate the contributions of FOV, peripheral vision, and the reference frame provided by the screen geometry.

Reference: Riecke, B., Van Veen, H.A.H.C., & Bülthoff, H.H. (2002). Visual homing is possible without landmarks - a path integration study in Virtual Reality. Presence: Teleoperators and Virtual Environments, 11 (5), 443-473.

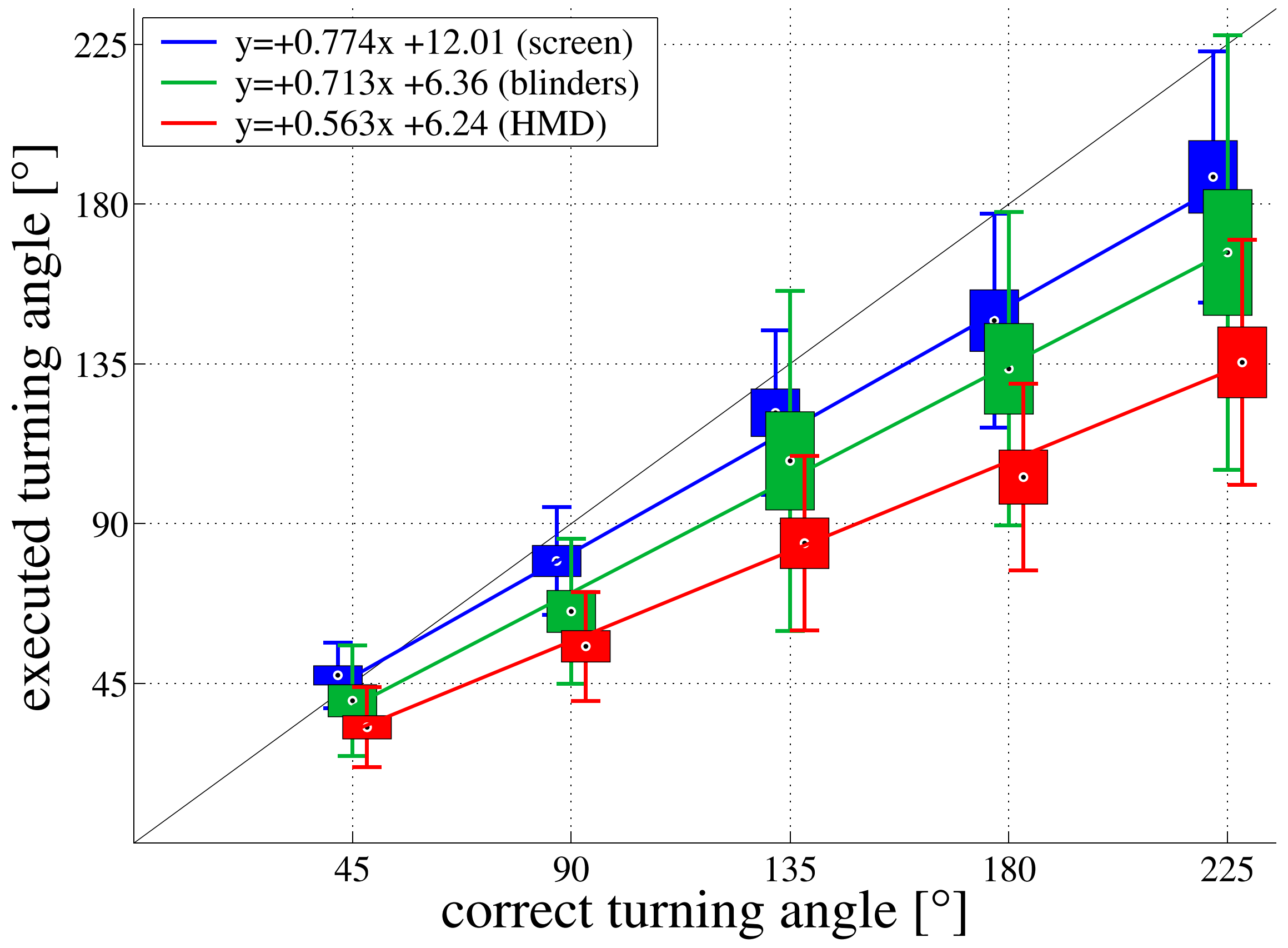

Figure 3: Means of turned angles per visualization condition plotted against the correct target angles. Boxes show one standard error of the mean, whiskers indicate one standard deviation. The slopes of the fitted lines correspond to the gain factors. The different slopes illustrate the interaction between condition and angle. The equations for the linear fit are shown in the inset on top. A gain factor of 1 describes perfect performance.

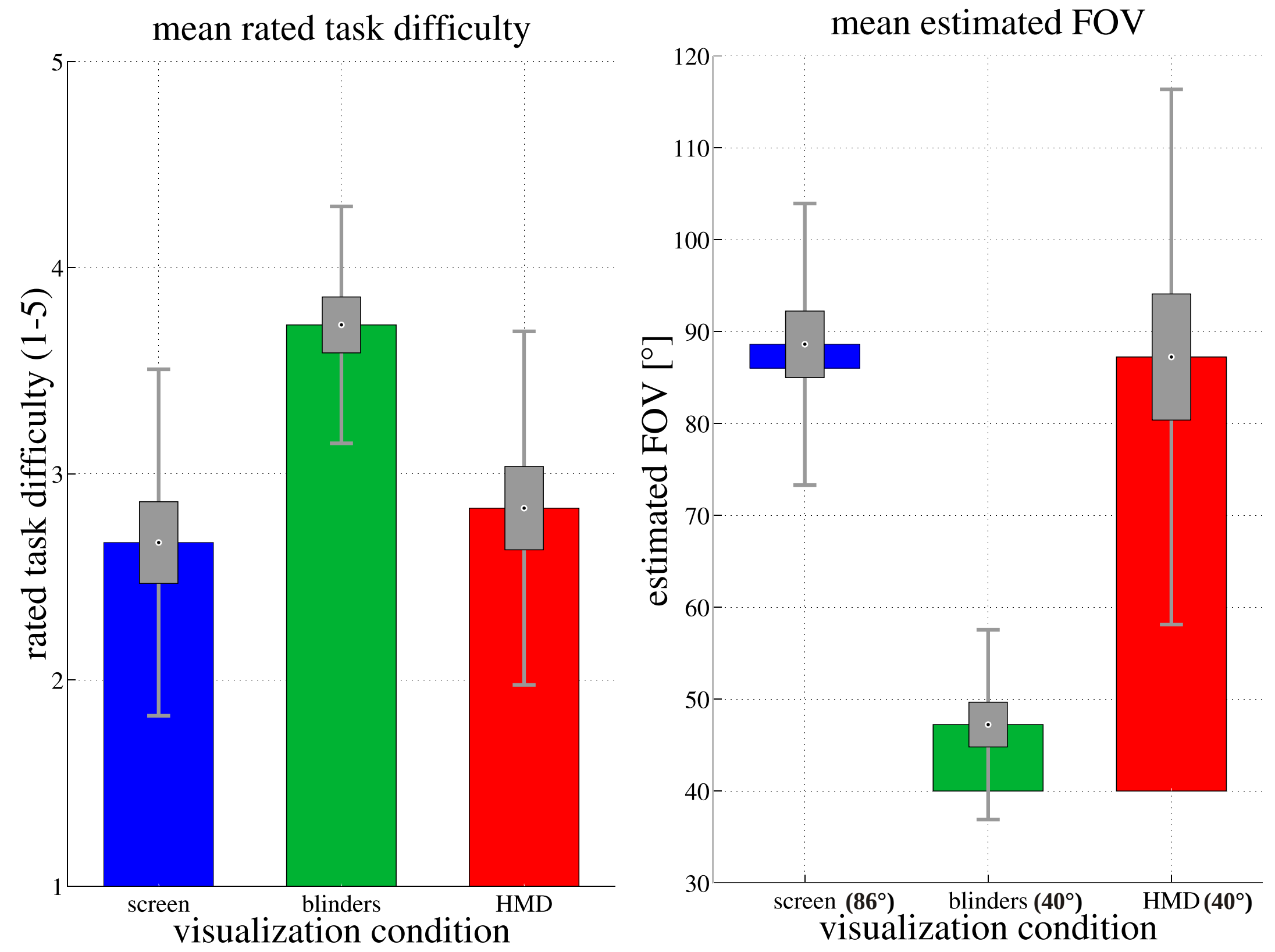

Figure 4. Left: Mean rated task difficulty. Boxes show one standard error of the mean, whiskers indicate one standard deviation.

Right: Mean estimated FOVs. The heights of the colored boxes indicate the amount of deviation from the actual FOVs.

Factor	***df* and F-value**	**Significance**
Visualization condition	F(2,24) = 13.3	p<0.001
Target angle	F(4,48) = 45.1	p <0.001
Visualization condition × Target angle	F(8,96) = 6.3	p<0.001
Presentation order	F(5,12) = 0.75	p=0.64

Table 1: ANOVA results

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