Influence of Visual and Body Rotation Cues on Helicopter Stabilization

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Introduction

In most experiments on multisensory integration in humans, participants report or discriminate distinct percepts.
In many natural tasks, however, sensory signals are not ultimately used only for perception, but rather for action.
The effects of actions are sensed again by the sensory system, so that perception and action are complementary parts of a dynamic control system.

- We studied the integration of different senses in a closed perception-action loop.
- **Question:** How are cues from different sensory modalities (visual cues and body cues) used when humans stabilize a simulated helicopter at a target location? Is their interaction consistent with maximum likelihood (MLE) integration?
- Helicopters in flight are unstable, much like an inverse pendulum, and hovering at one spot requires the pilot to do a considerable amount of active control.

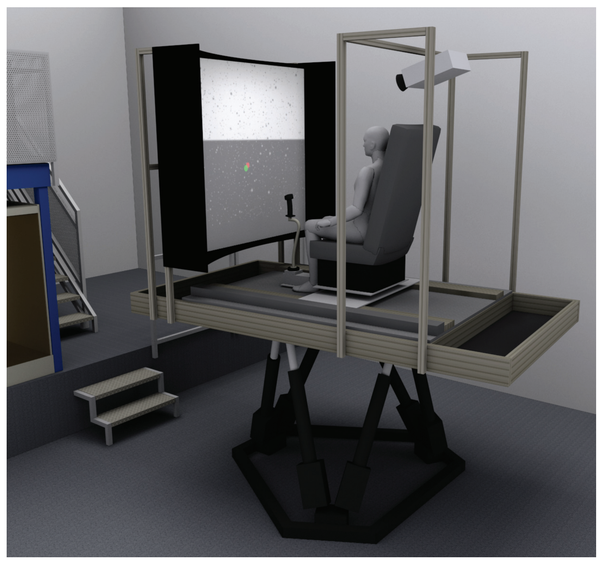

Figure 1: The Motion Lab - Hexapod platform and projection system mounted on the platform.

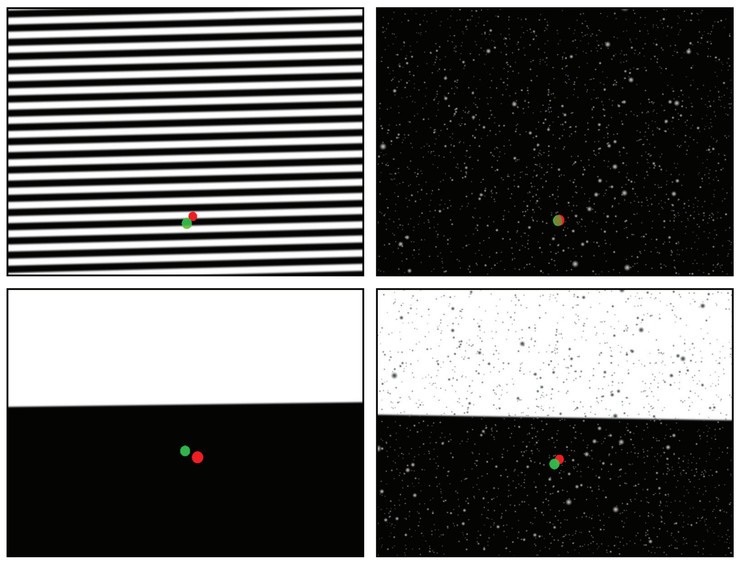

Figure 2: Visual stimuli used. Stripes (STR), optic flow defined by a random dot starfield (OF), horizon (H) and both horizon and optic flow (H+OF). The fifth condition has a black background (B).

Methods

- **Setup:** motion platform with projection screen (Fig. 1).
- Real-time simulation of dynamics and aero-dynamics of a small helicopter (Robinson R-22): three-body mass-spring rotor system and numerical approximations of the aero-dynamics (blade element theory) [1].
- 10 different **conditions** (see Fig. 2): black background (B), visual horizon (H), optic flow (OF), horizon+optic flow (H+OF) and horizontal stripes (STR), all with and without platform rotation motion cueing (P).
- Helicopter position and target position were indicated by two spheres.
- **Task:** stabilize pitch and roll axes by using a helicopter cyclic stick.
- **Measured variables:** stabilization performance in the different conditions using mean distance of the helicopter from the target, mean velocity, and mean tilt. n=6 participants.

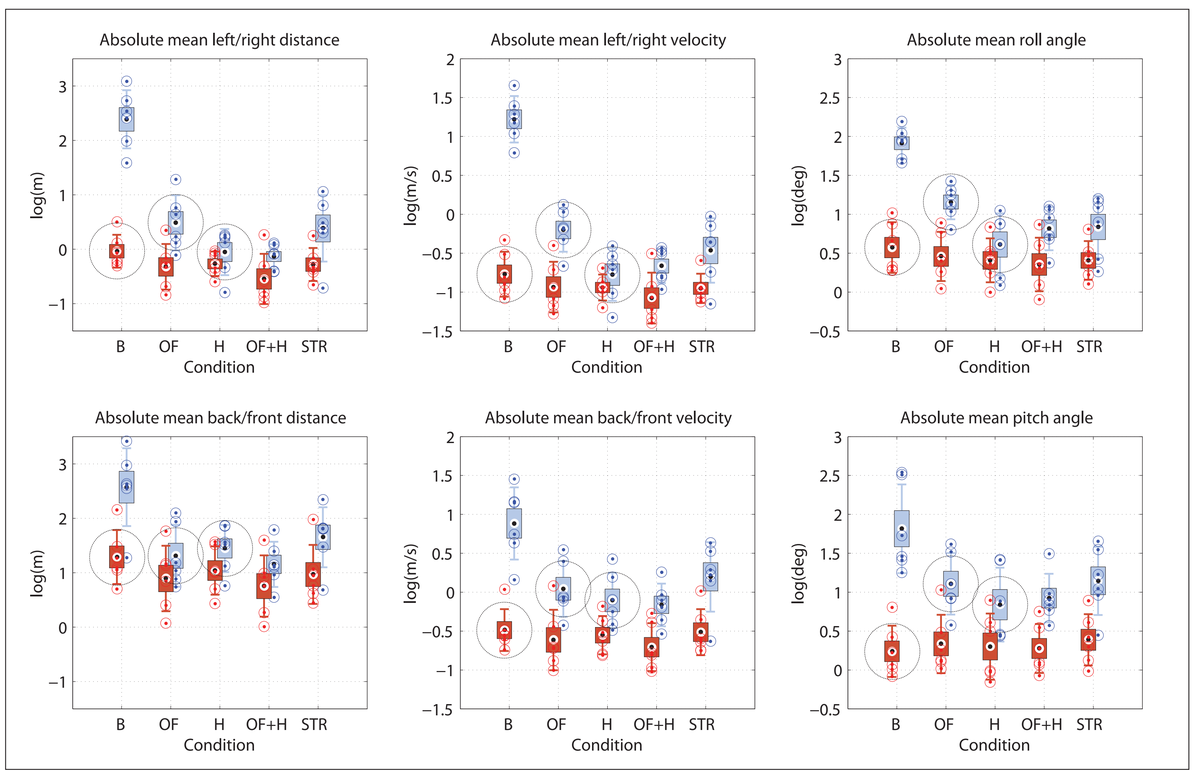

Figure 3: Results from all 6 participants. Platform-off conditions are shown in blue, platform-on conditions in red. B: black background, OF: optic flow, H: horizon, OF+H: optic flow and horizon, STR: stripes. Single-cue conditions are marked with circles.

Results

- All three cues, platform rotations, horizon and optic flow, significantly improved the stabilization. Platform rotations tended to help most, optic flow least (Fig. 3).
- Stabilization with only the two spheres as cues was impossible.
- Participants stabilized better laterally than fore/aft. (Fig. 4).
- The 'stripes' condition showed that horizon motion is more important for stabilization than horizon position.
- For some participants, adding cues always improved performance (qualitatively consistent with Bayesian cue integration), but for others there are conditions where adding a cue makes performance worse (Fig. 5).

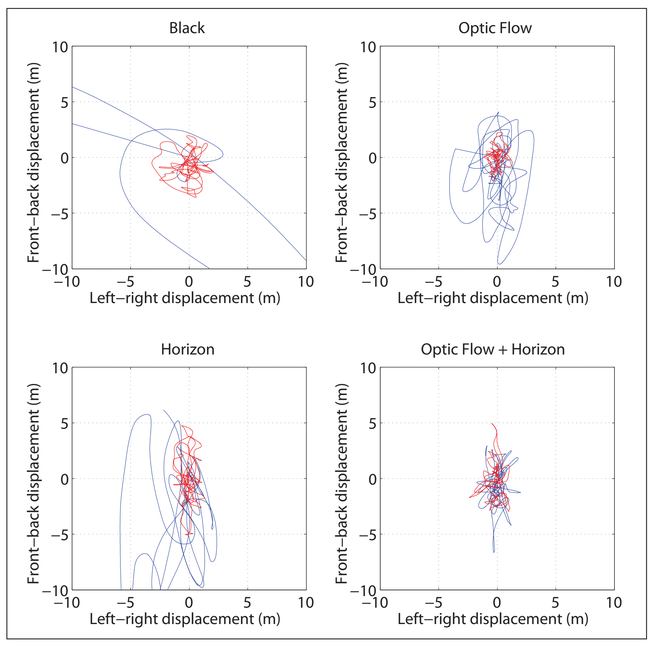

Figure 4: Example trajectories for one of the six participants in eight different conditions. Blue: platform off, red: platform on.

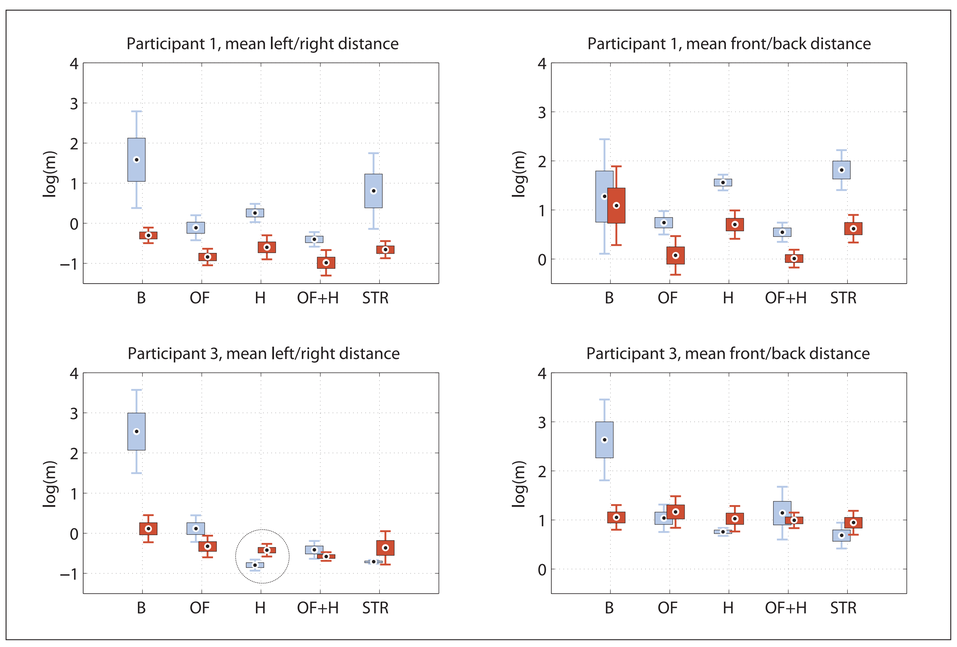

Figure 5: Responses of two example participants. Participant 3 shows MLE-contradicting responses in some conditions (circled).

Discussion

- Available sensory cues are combined to improve stabilization.
- Some participants showed MLE-contradicting effects when other cues were added to the horizon-only condition (Fig. 5).
- This provides possible evidence for a strategy switch.
- Model behavior as multi-stage differentiator controller (Fig. 6).

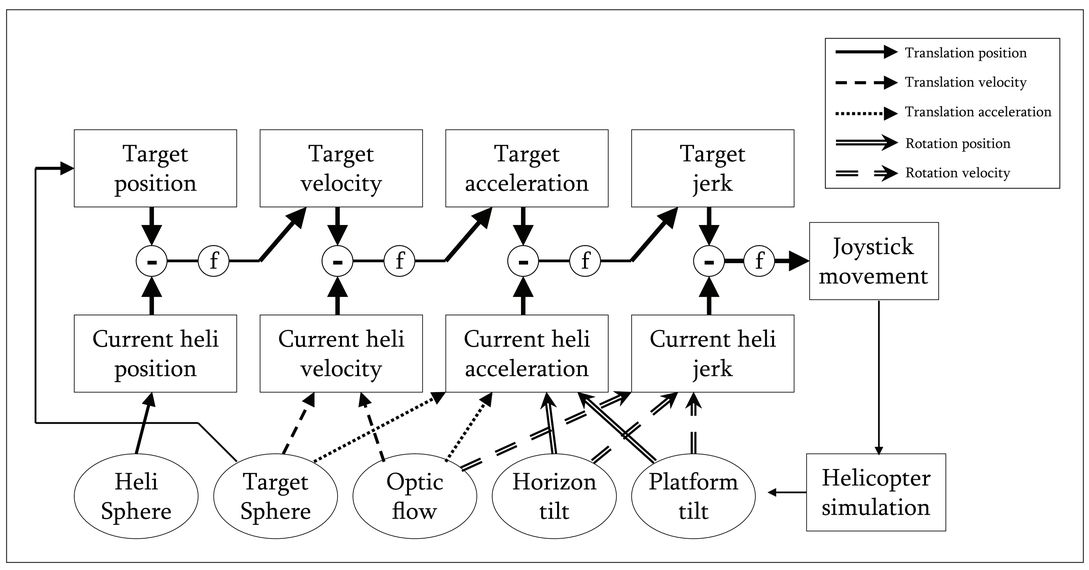

Figure 6: The helicopter pilot as a controller in a closed-loop system. f contains a factor 1/dt for the time derivative.

Mean	F=25.075 p=0.004**
D	F=251.61 p=0***
P	F=70.803 p=0***
D × P	F=7.124 p=0.044*
H	F=70.137 p=0***
D × H	F=19.144 p=0.007**
P × H	F=27.246 p=0.003**
D × P × H	F=55.93 p=0.001***
OF	F=47.582 p=0.001***
D × OF	F=1.678 p=0.252
P × OF	F=39.424 p=0.002**
D × P × OF	F=3.648 p=0.114
H × OF	F=21.786 p=0.005**
D × H × OF	F=10.165 p=0.024*
P × H × OF	F=14.962 p=0.012*
D × P × H × OF	F=18.144 p=0.008**

Table 1: Results of the four-way ANOVA for mean-distance-from-target measures (see Fig. 3 left column), with direction D (left/right vs. forward/backward), platform rotations P (on/off), horizon H (on/off), and optic flow OF (on/off) as within-subject variables.

Mean	F=17.972,	p=0.008**
D	F=247.055,	p=0***
P	F=6.934,	p=0.046*
D × P	F=1.001,	p=0.363
H/STR	F=2.009,	p=0.216
D × H/STR	F=88.724,	p=0***
P × H/STR	F=24.067,	p=0.004**
D × P × H/STR	F=2.224,	p=0.196

Table 2: Results of a three-way ANOVA testing the effects of horizon vs. stripes.

Outlook

- Identify the pilot model parameters (Fig. 6) [2].
- Characterize the multisensory integration processes.
- Compare different physical motion cueing algorithms.
- Helicopter control using all four DOF.
- Larger physical trajectories: MPI robot arm simulator.
- Simulators for pilot training: study transfer to real helicopters.

References:
[1] C. Terzibas (2004). Entwicklung eines Hubschraubersimulators zur Untersuchung der Lagestabilisierung mit visuellen und vestibulären Reizen. Master's thesis, Universität Tübingen, Germany.
[2] P. Zaal, F. Nieuwenhuizen, M. Mulder, and M. van Paassen (2006). Perception of Visual and Motion Cues during Control of Self-Motion in Optic Flow Environments. AIAA-2006-6627, AIAA Modeling and Simulation Technologies Conference and Exhibit, Keystone, Colorado, Aug. 21-24, 2006.

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