Introduction

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.

Which senses do pilots use to stabilize a helicopter? It is assumed that they do not only use visual information, but also vestibular and somatosensory cues. To test this hypothesis, we measured helicopter hovering performance of human subjects in a simulator. We compared stabilization performance in four body motion cueing conditions: no body motion, rotations, translations, and both rotations and translations.

Methods

- Participants: 7 male students and post-docs from our institute
- Setup: 6 degrees-of-freedom Stewart motion platform with a projection screen of 70° x 54° visual field (Figures 1, 2)
- Visual stimulus: computer-generated scene consisting of a textured ground plane with a ball as a target, and a second ball as helicopter position marker (Figure 3)
- Helicopter simulation: dynamics and aerodynamics of a small helicopter (similar to a Robinson R-22) were simulated in real-time by using a three-body mass-spring rotor system and numerical approximations of the aerodynamics of helicopter flight (blade element theory)
- Flight control: the participant controlled three of the four axes of the simulated helicopter: pitch (controlling forward/backward accelerations), roll (controlling sideways accelerations), and yaw rotation (controlling heading direction).
- Motion cueing: rotations: the orientation of the helicopter in space was used directly to set the platform orientation. Translations of the platform were derived from translations of the simulated helicopter by using a washout function implemented by a simulated inertial mass on a damped spring.
- Experimental design: 48 trials in four blocks. In each block, the conditions were repeated three times in a ABCD sequence. A different sequence was used for each block. Each trial had a duration of 120 seconds.
- Measured variables: roll and pitch angles, the distance of the position marker from the target in front-back and sideways directions, and the helicopter velocity.

Results

Stabilization was more accurate for the left/right than for the front/back direction (Figures 4, 5). Platform rotation motion cueing significantly increased the stabilization performance for most of our measures (Figure 4).

Discussion

This experiment showed that body motion cues can significantly increase stabilization performance of a simulated helicopter. For helicopters, tilt (pitch and roll) determines the direction of acceleration. Immediate feedback of tilt can therefore tell the pilot in which direction he is accelerating, even before he can perceive the acceleration visually.

The beneficial effect of platform rotations on the stabilization was larger than the influence of platform translations, possibly because the translations could not be simulated accurately. The small translation range of the platform makes the use of wash-out filters necessary. Those filters introduce a mismatch between the actual and the simulated helicopter motion.

From our simulator studies we conclude that helicopter pilots also use vestibular and proprioceptive cues for the stabilization of real helicopters. These findings have important implications for the design of helicopter simulators for pilot training, because it might not be necessary to control all motion cues with the same amount of precision.