Spatial Disorientation and Expectation When Reading Flight Instruments:

An In-Flight Study

INTRODUCTION

Spatial disorientation has been identified as a significant hazard in aviation [1]. Pilot expectation, startle and upset recovery training are active areas of research following several commercial air transport accidents in which spatial disorientation has been identified as a causal factor [2] [3]. This in-flight study investigated the effect of spatial disorientation on error rates when using an Attitude Indicator (Figure 1) to control an aircraft in roll, continuing from a similar experiment in a fixed-base simulator [4]. The experiment involved 40 non-pilot subjects flown in the National Flying Laboratory Centre's Bulldog aircraft (Figure 2) at Cranfield University, in collaboration with TNO and TU Delft in the Netherlands.

Figure 1. A Typical Attitude Indicator

Figure 2. The NFLC Bulldog Aircraft

METHOD

Each subject was given a period of familiarisation with the aircraft's roll controls. For the tests, subjects were blindfolded while the pilot flew gentle rolling manoeuvres; then subjects removed the blindfold and were asked to return the aircraft to the wings-level condition **using only the attitude indicator for reference.** Responses and attitude data were recorded with a video camera and an inertial measurement unit (Figure 3).

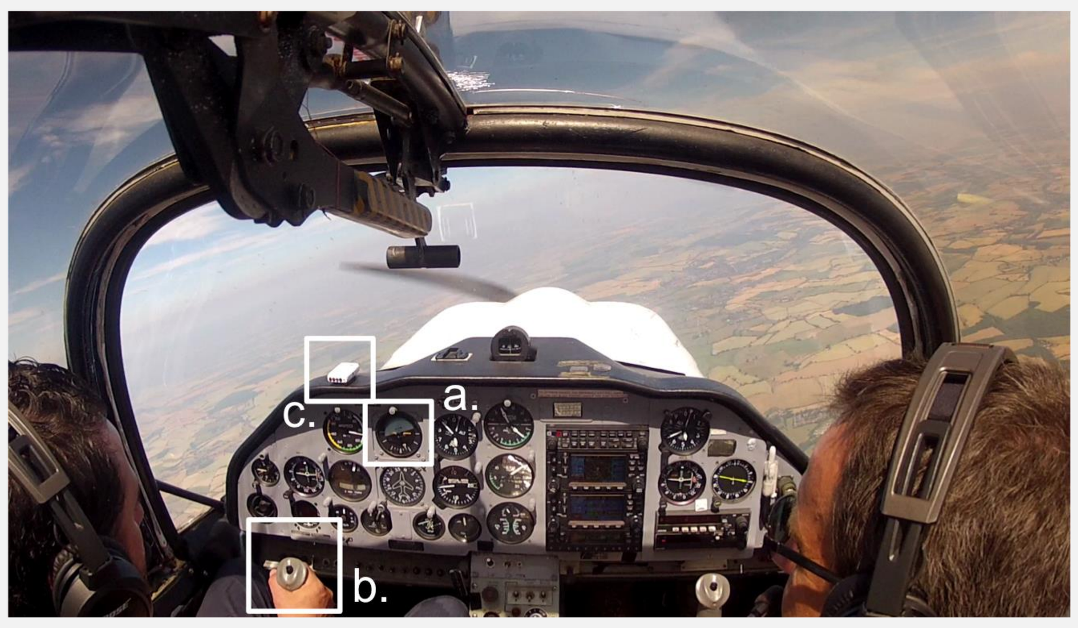

Figure 3. A screenshot of the cockpit video, showing (a) the AI, (b) the subject holding the centre-stick, and (c) the inertial measurement unit.

Four test conditions were flown; a matching 'practise' test, followed by three tests designed to deliberately induce spatial disorientation in the subject using slow rolls below the threshold of detection of the vestibular system (Figure 4).

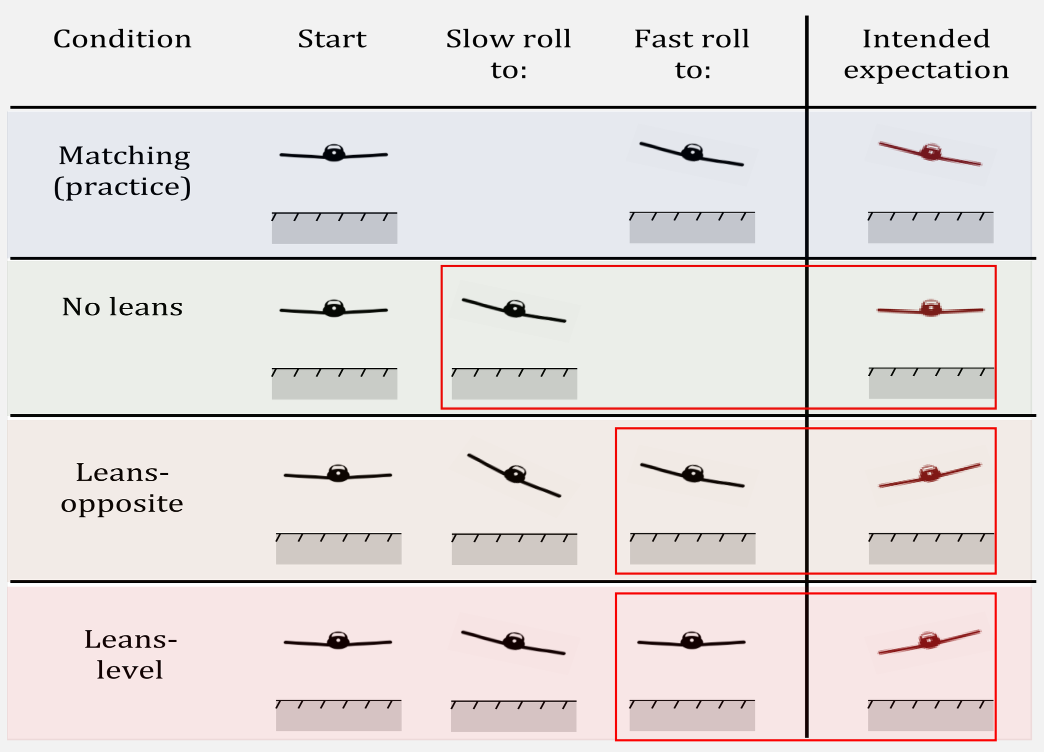

Figure 4. The practice and test conditions, with the flown manoeuvres and the intended expectation of the subject (right).

RESULTS & DISCUSSION

Error Rates

When spatial disorientation was induced, subjects were significantly more likely to make an error in the direction of roll applied when taking off the blindfold, (Figure 5).

Both conditions involving leans ('Leans-level' and 'Leans-opposite') produced error rates about 2.7 times higher than the 'No leans' condition, confirming our key hypothesis.

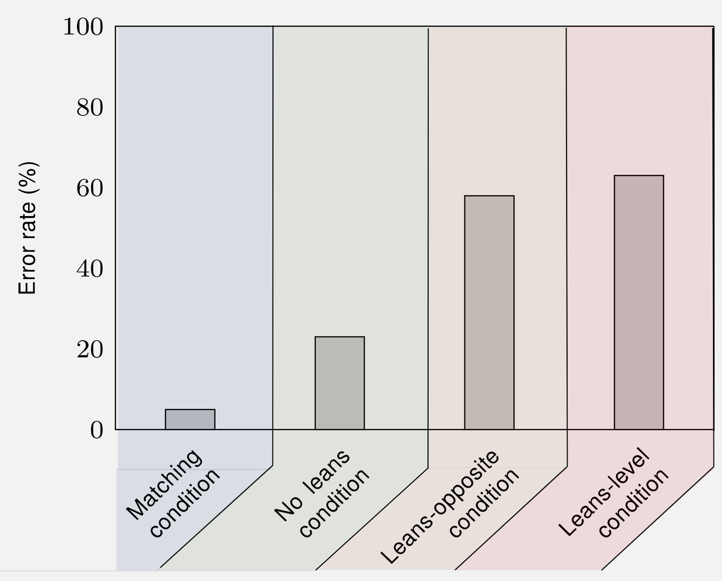

Figure 5. The mean error rates in the Matching condition and in the three test conditions. Red shaded area indicates conditions of induced disorientation.

There was a much higher rate of errors in the 'Leans-level' condition (63 %) compared to the fixed-base simulator experiment of Landman et al. (2018, 30 %) [4], in which participants were manipulated to expect a turn while the AI indicated level flight. **This suggests that vestibular cues had a stronger influence on the first response than the manipulation of expectation with a flying task in the fixed-base simulator.**

Contrary to our hypothesis, the error rates were not significantly different between the 'Leans-level' and 'Leans-opposite' conditions. This may have been due to a requirement for subject control input in all other conditions; the design of future experiments may be improved by including some similar 'level' practice runs.

Typical Subject Response

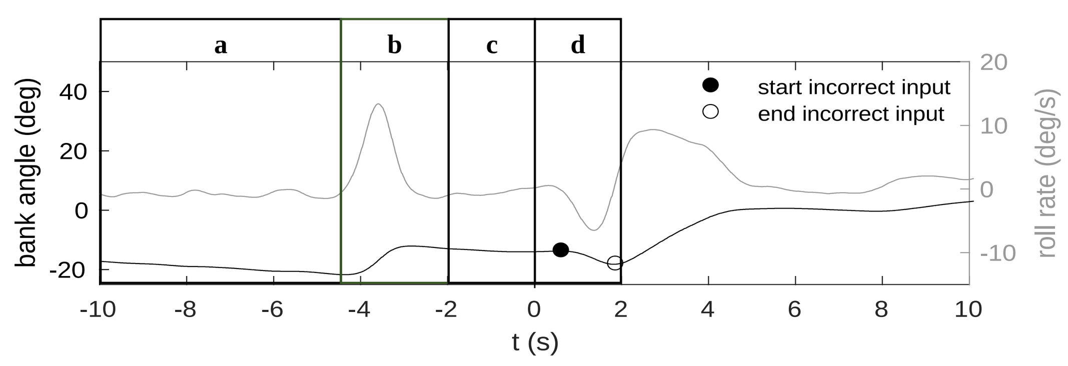

Figure 6. An example of an incorrect response in the 'Leans-opposite' condition:
(a) Initial, sub-threshold roll to 20° bank at around 1°/sec;
(b) A rapid roll back to 10° bank, peaking at around 13°/sec;
(c) Blindfold is removed and subject takes control of the aircraft;
(d) The subject responds incorrectly, rolling away from level for about 2 seconds, before correcting and rolling in the other direction.

Reaction Times

There was no difference between erroneous and correct responses in the 'No leans' condition, but the reaction times of errors in the 'Leans-opposite' condition were .28 seconds shorter than the correct responses (Figure 7). **This result is consistent with the hypothesis that subjects who took slightly longer to assess the AI display are more likely to respond correctly.**

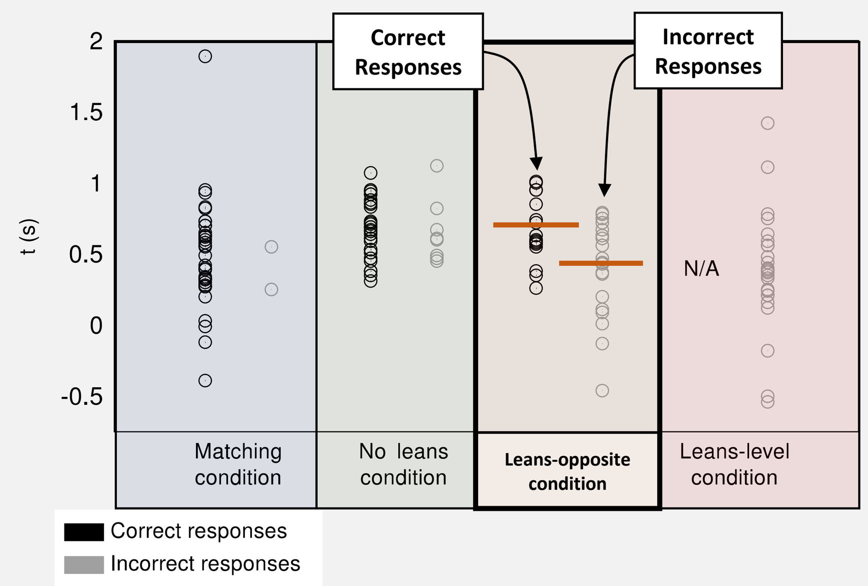

Figure 7. Scatterplots of the reaction times of the correct responses and incorrect responses.

CONCLUSIONS

- The results suggest that pilots experiencing spatial disorientation, or are otherwise surprised by the aircraft attitude, are more prone to make an error while attempting to correct from an upset.
- It may be useful to provide additional advice to the pilot to alert them that they have been subjected to a manoeuvre likely to induce spatial disorientation as an aid to upset recovery; this could be based on existing multi-sensory models to predict spatial disorientation events.
- Promisingly, participants were better able to prevent errors when they took more time before responding. This supports the drive to provide enhanced upset recovery training to help pilots prevent incorrect, intuitive responses. It may thus be wise to not only teach pilots to "Believe your instruments." but also to "Control the aircraft to make the instruments read what you want them to." (Bles, 2008) [5].

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Annemarie Landman[1,2], Simon Davies[3], Dr Eric Groen[2], Dr René van Paassen[1], Prof. Nicholas Lawson[3], Prof. Adelbert Bronkhorst[2], Prof. Max Mulder[1]

[1] TNO Human Factors, Soesterberg, The Netherlands - eric.groen@tno.nl
[2] Delft University of Technology, The Netherlands - h.m.landman@tudelft.nl
[3] Cranfield University, United Kingdom - s.g.davies@cranfield.ac.uk

www.cranfield.ac.uk