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K. Wolfgang Kallus

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PSYCHOLOGICAL FIDELITY OF SIMULATOR HUMAN PERFORMANCE LIMITATION TRAINING

K. Wolfgang Kallus
Karl-Franzens-University Graz
Graz, Austria

Problem

Fidelity of simulators for training of pilots has to be judged from the final end of the training goal. This conclusion can be derived from the overview of Hays & Singer (1989), which has been published a considerable time ago. Nevertheless, an ongoing debate questions the need of simulator features like motion for the training of pilots – partly without giving attention to the training goals at hand. Especially in the area of threat and error management requirements for the simulators differ markedly from operational recurrence training. For experienced ATPL- pilots we can assume that a high fidelity visual simulation and a proper representation of the avionics and a high fidelity simulation of the flight dynamics might well be sufficient to refresh rare standard situations. From a psychological point of view we would predict that the well elaborated cognitive model of professional pilots with respect to aircraft, its dynamics and the situation will allow to simulate the situations without motion. Pilots are able to add the not simulated aspects from their highly elaborated mental model. On the other hand a broad range of situations in the area of human performance limitations are beyond the experience of pilots or trainees. A proper simulation of the aircraft performance and the perceptions and sensations is necessary to improve performance by simulator training to cope with situations beyond the standard environment. Especially for successful disorientation recovery training it may be necessary to provide the correct physical sensations enable the pilot to learn the correctly timed and executed actions to re-establish safe flight parameters. Perceptual illusions of the vestibular system and problems in vestibular-optic coordination are core elements in the development of a multitude of spatial disorientation phenomena (Bles, 1998; Cheung, 2004; Previc and Ercoline, 2004). A couple of reports have been published, which show convincingly that disorientation recovery training with a motion base simulator improves performance in jet pilots (Cheung, 2004; Kallus & Tropper, 2004) as well as in helicopter pilots (Hays & Singer, 1989) and in pilots of small VFR aircraft (Kallus, Tropper & Boucsein, 2009). These studies all used simulators, which are at least capable to rotate in one axis. Disorientation due to sensory illusion is not only caused by vestibular illusion (like gyro spin or leans, for details see Previc & Ercoline, 2004 or Kallus & Tropper, 2004). Some accidents in the area of spatial disorientation occur primarily due to visual illusions (like the black hole approach or the runway width/slope illusion). For VFR pilots, flight into IMC is one of the most problematic and often fatal causes of disorientation. Unintended flight into IMC due to gradually worsening weather conditions seems also to be a primarily visual problem. The more visually based disorientation situations might not require motion cues during the training, as motion does not seem to play a predominant role in the development of the state of disorientation. An experimental study was designed to evaluate the role of motion cues for different disorientation recovery exercises in the simulator.

Methods

Subjects and experimental conditions

Forty-two pilots with a valid PPL-license participated in the experiment. Age ranged between 20 and 56 years (M = 41.2 years, SD = 8.7). Only pilots without IFR-rating and with less than 500 fight-hours were admitted to the study.
The 42 pilots were randomly assigned to one of three groups: The training-motion group (n=15) received a disorientation recovery training, which was based on the successful procedures of a previous study (Kallus, Tropper & Boucsein, 2009). A second group received an identical training without motion. For the training-no motion group (n=15) the motion function of the simulator was switched off during training sessions. In addition a control group was studied under motion conditions. The control-motion group (n=12) did not receive a specific training, but had to execute free flights and some of the flight maneuvers of the experimental groups (e.g. approaches) under standard conditions to equal the simulator experience. Table 1 summarizes the experimental conditions.

Table 1. *Experimental conditions.*

	simulator phase I	**simulator phase II**	**simulator phase III (test)**
TG_MO (N = 15) training group motion	**familiarization flight** MOTION ACTIVE	**training** MOTION ACTIVE	**test** (5 test profiles) MOTION ACTIVE
TG_noMO (N = 15) training group no motion	**familiarization flight** NO MOTION	**training** NO MOTION	**test** (5 test profiles) MOTION ACTIVE
CG_MO (N = 12) control group motion	**familiarization flight** MOTION ACTIVE	**free flight control condition** MOTION ACTIVE	**test** (5 test profiles) MOTION ACTIVE

Procedure

A motion base flight simulator (AIRFOX spatial disorientation trainer DISO by AMST Systemtechnik GmbH, Austria, 2006) was used for training and test. The exercises were performed with a two engine turboprop aircraft model. The experiment took place in three subsequent phases: instruction, training, and test. Instruction and test was identical for all subjects.

The following exercises were used for training:

- Pitch up illusion (by configuration change just after take off under minimal visibility conditions),
- Inadvertent Flight into IMC (climbing to 3000ft under deteriorating weather conditions),
- Unusual approaches (black hole approach and approaches with tilted or narrow runway)
- Unusual attitude recoveries (returning the aircraft to near straight and level flight from an unexpected bank and/or pitch angle)
- spin recoveries and a gyrospin demonstration

The test exercises in phase 3 correspond to the training exercises. Motion was on for all groups during the test exercises

Measures

The study was conducted in a multivariate multilevel assessment approach, only performance data (observation data, instructor ratings, time-measurements, self-assessment) will be reported here. For detailed results on the psychological and physiological state before, during and after the exercises see Kallus, Tropper & Boucsein (2009).

<u>Objective performance data</u> were time to regain safe flight parameters was taken for UAR recoveries and spin recoveries. A blind scoring of performance was conducted for the other profiles using a five point rating scale with objective rating criteria for each of the five categories. These ratings were based on flight recordings using the digital video recording system of the DISO Airfox simulator.

<u>Instructor ratings</u>. The instructor rated the pilots' flight performance immediately after each exercise according to the following six evaluation criteria: allocation of attention, situation awareness, stress resistance, multi tasking, aggressiveness, and overall performance. Ratings used four categories: excellent (4), good (3), fair (2), and unset (1). For each category, five subcategories were available: double minus, minus, middle, plus, and double plus. Thus, the whole scale ranged from 0.6 (unset, double minus) to 4.4 (excellent, double plus). As the unusual attitude recovery sequences were of short duration (average about 13 sec per UAR), the instructor rated the overall performance for each UAR.

<u>Self-ratings</u> of performance using the same rating scale were obtained during a reconstruction interview, which was conducted after the test phase with each pilot.

Statistical analyses

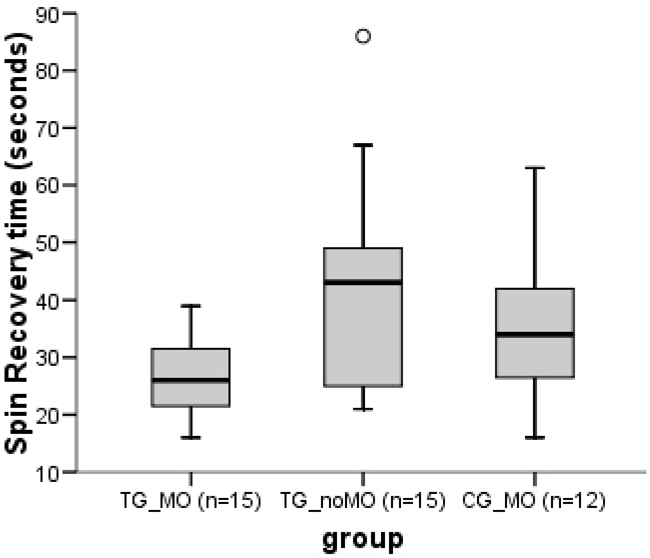
The performance data were analyzed with a multivariate analysis of variance and the instructor ratings were analyzed with a repeated measures analyses of variance for a controlled statistical decision with alpha=0.05 and Bonferroni-Holm adjustment (Holm, 1979) for multiple testing. In a second step a traditional statistical analysis was conducted using analyses of variance procedures for self rated performance.

Results

Objective performance data

The statistical analyses of the performance data from the test phase resulted in clear cut group-effects below the adjusted type-I-error of α=0.05. Thus, it can be concluded that training effects could be proved with a type-I-error of 5%.

The motion based training outscored the other two groups in the test profiles, which resulted in a highly significant statistical effect (F(10,72)=3.06, p=0.003). Univariate analyses show that the positive training effects are most prominent in the profiles “Take-off with Pitch-up Illusion” (F(2,39) = 6.68, p = .003), “Inadvertent Flight into IMC” (F(2,39) = 5.14, p = .010), and “Spin Recovery” (F(2,39) = 4.87, p = .013). Figure 1 depicts the results of the spin recoveries as box-whisker-plots, which show means (bars), interquartile distances (boxes), and the 95% intervals (whiskers). In addition outliers are shown if present (single points).



TG_MO training group motion
TG_noMO training group no motion
CG_MO control group motion

Figure 1. Boxplots for the spin-recovery time for the three experimental groups.

The results of post-hoc tests (Tukey-test) are depicted with stars. For the profiles “spin recovery” the training without motion showed the worst performance indicating a “negative training” effect in this motion oriented profile. Similar results were obtained for the profile “pitch-up illusion”. Even for inadvertent flight into IMC the only significant effect was obtained for the motion-based training, which differs significantly from the control condition. In this profile the training without motion results in an intermediate performance. Additional analyses for the objective data with a repeated measures analysis to check for interaction between training effects and the kind of profile (using profile as repeated measure after standard-normal-transformation and alignment of scoring direction) resulted in a significant interaction term (F(8,156) = 2.51, p = .014) indicating that the differences in effects for the different profiles are substantial.

Instructor ratings

The repeated measures analysis of variance all in all show corresponding results to the objective performance data with a significant main effect for the training condition (F(2,39) = 8.47, p = .001).

Self-rating of performance

Differences in performance were also represented subjectively. Significant effects emerged in the performance ratings of NASA TLX (F(2,39)=5.38, p=0.009). The motion based training resulted in better subjective performance compared to the controls and to the no-motion training. Again the no-motion training does not differ substantially from the control group.

Discussion

The results fit well into a mental training framework of simulator training. Motion oriented test procedures profit a lot from motion cues during training. A profile like spin recovery, which has a complex, partly contra-intuitive recovery procedure showed no training effect with the training based only on visual cues. Motion enhanced performance significantly compared to the no-motion training group. Without motion it might have been impossible (or at least much more difficult) to obtain a proper mental representation of the situation. Considering that VFR-Pilots do not have access to motion simulators a preparation for situations like spin recoveries is not possible during simulation. An acrobatic aircraft trainer is the only option to learn procedures like spin recoveries properly in Europe as long as Disorientation training simulators like the DISO Airfox are not accredited in the pilot's training syllabus. The main reason for this is the generic avionic, which works well – but is not a face valid naturalistic representation of a VFR aircraft. The option to use more generic simulators for specific training purposes has also been claimed by Dahlström et al. (2009). They also argue that the mere reliance on increased photorealistic fidelity of simulation systems can be the wrong path to follow for a couple of training goals. For the training of a couple of no-tech-skills technical fidelity might even distract the attention from the training goals towards technical details of the simulated situations. Our data strengthen the view, that training simulators have to mimic the relevant cues as realistic as possible. Cues outside the focus can be simulated in a very generic way, especially, when the trainees can fill in their correct mental representation. Of course – basic principles of mental training should be met, when technical simulation and metal representations are used in a training paradigm. The data provided with the disorientation trainer DISO AIRFOX show that motion cues during training are crucial for an adequate test performance. The results given in figure 1 rise the problem of possible negative training effects. These effects occur if the simulated training situation results in a response pattern or a mind set, which is dysfunctional in the aircraft. Motion is a basic feature of every aircraft – thus exclusion of motion cues from training might cause problems in the long run. As full flight simulators are unable to simulate extreme (motion-)situations the requirement to include more motion axes into the training seems inevitable especially for pilots, who are at risk of extreme motion situations in their operational environment. This is especially true for helicopter pilots and military pilots.

For trainings of human performance limitations we currently face the paradoxical situation, that JAR-FCL require substantial knowledge of human performance and human performance limitations from CPL and ATPL certified pilots, while PPL licences only have to know the basics (probably without any option to make this knowledge relevant for their decision making in disorientation prone flight situations). To provide extended knowledge to the better educated pilots is useful – but in large commercial aircraft there is a much lower probability of disorientation prone situations. For VFR pilots the knowledge might be life saving, especially if it is transferred into action relevant mental models, which trigger recovery and adequate decision making.

References

Bles, W. (1998). Coriolis effects and motion sickness modelling. *Brain Research Bulletin*, 47(5), 543-549.

Cheung, B. (2004). Spatial Orientation – Nonvisual Spatial Orientation Mechanisms. In: F. Previc, W. Ercoline (Eds.) *Spatial Disorientation in Aviation. Progress in Astronautics and Aeronautics*, Vol. 203, 37-94. American Institute of Aeronautics and Astronautics, Inc. Restoin, Virginia.

Cheung, B. (2004). Spatial Orientation – Nonvisual Illusions in Flight. In: F. Previc, W. Ercoline (Eds.) *Spatial Disorientation in Aviation. Progress in Astronautics and Aeronautics*, Vol. 203, 243-281. American Institute of Aeronautics and Astronautics, Inc. Restoin, Virginia.

Dahlström, N., Dekker, S., van Winsen, R. & Nyce, J. (2009). Fidelity and validity of simulator training. *Theoretical Issues in Ergonomic Science*, in print.

Hays, R. T. & Singer, M. J. (1989). *Simulation fidelity in training system design – bridging the gap between reality and training*. New York: Springer.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65-70.

Kallus, K. W. & Tropper, K. (2004). Evaluation of a Spatial Disorientation Simulator Training for Jet Pilots. *International Journal of Applied Aviation Studies*, 4(1), 45-55.

Kallus, K. W., Tropper, K. & Boucsein, W. (2009). The Importance of Motion Cues in Spatial Disorientation Training for VFR-Pilots. *International Journal of Aviation Psychology*, submitted.

Previc, F. H. & Ercoline, W. R. (2004). Spatial disorientation in aviation: Historical background, concepts, and terminology. In F. H. Previc & W. R. Ercoline (Eds.), *Spatial Disorientation in Aviation* (pp. 1-36). Virginia: American Institute of Aeronautics and Astronautics.