NOISE-REDUCED LANDING APPROACHES AND PILOTS' WORKLOAD

E.-M. Elmenhorst, H. Maaß, M. Vejvoda, A. Samel†
German Aerospace Center (DLR), Institute of Aerospace Medicine
D-51170 Cologne
Germany

OVERVIEW

Due to the intense growth of air traffic, associated noise emissions and possible impairments for health and well-being of residents are the basis for highly controversial debates. Sophisticated countermeasures that exceed the common procedures on the ground have to be developed to protect residents against noise immissions. One short- or medium-term countermeasure is the implementation of noise reduced landing procedures. To assure flight safety, operability and acceptance of aircrew members, a noise reduced, steep gradient "segmented continuous descent approach (SCDA)" was compared to a standard "low drag low power (LDLP)" procedure.
40 pilots were examined conducting one LDLP and three SCDA procedures on either an Airbus A320 or an A330 full-flight simulator. The pilots conducted each procedure twice, due to switching tasks between flying and non-flying pilot. Technical, physiological, and psychological data were monitored using the recordings of electro-physiological parameters (EEG, EOG, ECG), saliva cortisol, and questionnaires (fatigue, task load, acceptance). LDLP served as reference scenario.
Task load and fatigue scores, stress hormones, heart rate and blood pressure did not differ significantly between the approach procedures. SCDA was rated rather non-problematic, and workload was in an acceptable range. However, pilots rated SCDA as being less safe than LDLP. The approaches were conducted under closely controlled environmental conditions. Under these ideal premises the noise reduced SCDA procedure has proven to be operable. Before discussing any introduction into common practice, further studies are strongly recommended, e.g. under real flight conditions.

1. INTRODUCTION

The intense growth of air traffic and associated noise emissions cause highly controversial debates in research and society. Residents living in the vicinity of airports are annoyed and fear long-term effects for health and well-being. Increasing aircraft movements during nighttimes may cause disturbances of sleep and subsequently may generate fatigue and decrements in performance during the next day. Reducing the noise load is important to assure future air traffic growth. Long-term counter-measures like the development of less noisy aircrafts are needed, but short- or medium-term measures that complete the common protection measures on the ground are of special interest. Implementation of noise reduced approach procedures to airports is one possibility. However, aviation safety must be secured since the technical and human operability, acceptance and workload may change compared to standard approach procedures.
Therefore, within the research field „Quiet Traffic", funded by the German Federal Ministry of Education and Research, a new approach procedure was examined with respect to flight safety and acceptance by pilots. This research activity was initiated in 2002, conducted in 2003 and 2004, and completed in 2005. The partners of the investigations were the DLR-Institute of Aerospace Medicine, DLR-Institute of Flight Systems, Lufthansa German Airlines, and Technical University of Berlin - Institute of Aeronautics and Astronautics.

2. METHODS

The approach scenarios (Fig. 1) were either a standard landing procedure (LDLP) which served as control condition, or a steep gradient approach (SCDA) which was calculated to reduce immission noise [1]. The full-flight simulators A320-200 in Frankfurt/Main (Lufthansa Flight Training) and A330 in Berlin (Centre for Flight Simulation) were used to simulate approaches to Munich airport. 40 pilots (38 males) participated in the experiment (20 Captains + 20 First Officers), 20 pilots each in Frankfurt or Berlin, respectively. The average age was 37.3 ± 7.9 years. Their professional experience as flying pilots averaged 11.4 ± 7.1 years, their flying hours 6351 ± 3567, so they may be classified as experienced pilots. Since it is assumed that advanced noise reduced approaches will be at first conducted during night hours due to lower traffic density, the test sessions were performed between 2300 and 0300 h. One Captain and one First Officer were studied per night completing 4 approach scenarios. Each of the 4 approach scenarios was conducted two times: first, the Captain was the actively flying pilot, afterwards the First Officer was the actively flying pilot. The first scenario was performed as an usual LDLP, the second scenario was intended to train for the SCDA (SCDA 1/2). Thereafter, the SCDA was repeated another 2 times (referred to as SCDA 3/4 and SCDA 5/6). A break of about 20 minutes was provided after the completion of the first 2 test scenarios. Each flight simulation commenced at a flight level of 9000 feet and was finished after landing (touch down) and stop of the aircraft on the runway, lasting about 13 minutes. The pilots were accompanied by a flight instructor who was asked to give an additional assessment of the simulated flights concerning pilots' performance and procedures. Physiological measurements comprised recordings of electroencephalogram (EEG), electro-oculogram (EOG), electrocardiogram (ECG), blood pressure, and saliva samples for later determination of concentrations of the stress hormone cortisol. Questionnaires regarding fatigue [2], task load [3], and acceptance were applied after each flight procedure. A repeated measures ANOVA was conducted for statistical analyses using SPSS software.

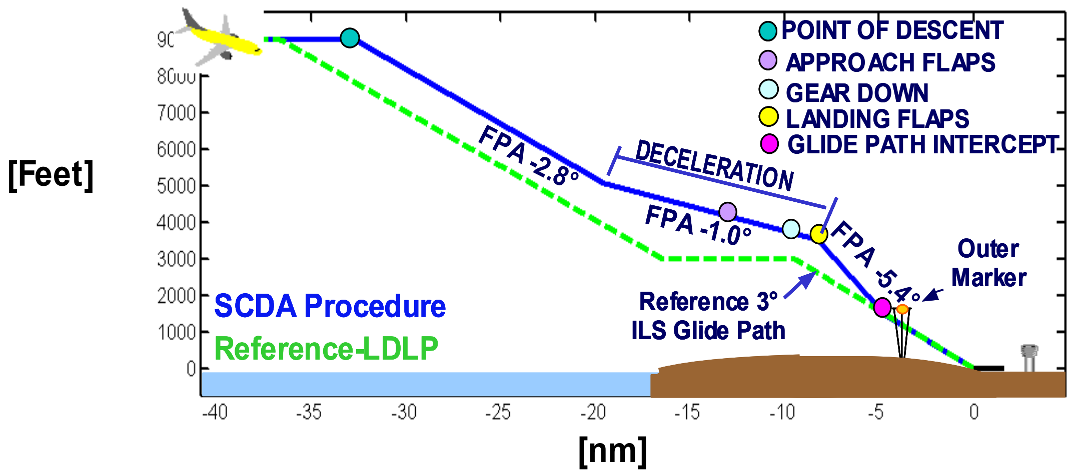

FIG 1. Segmented Continuous Descent Approach (SCDA) procedure and Low Drag Low Power (LDLP) approach procedure as reference, as calculated and proposed by DLR-Institute of Flight Systems.

3. RESULTS

This paper presents an excerpt from the obtained data. A full report of the project was published as a research report (in German language) [4].

3.1. Physiological data

3.1.1. Heart rate

Mean heart rates were calculated for each scenario from the beginning of the simulation to the stop on the runway. The heart rate of the actively flying pilot was usually higher than that of the non flying pilot, though not significantly different (p=0.089).

The mean heart rates during the SCDA scenarios of the flying and non flying pilots were rather reduced compared to the LDLP procedure (Fig 2). Fig 3 gives an example for the course of the heart rate during the simulation. For some flying pilots an increase in heart frequency was observed during the last segment of the approaches (pivot on the glide slope until touchdown and standstill on the runway). This increase was present in the LDLP as well as in the SCDA.

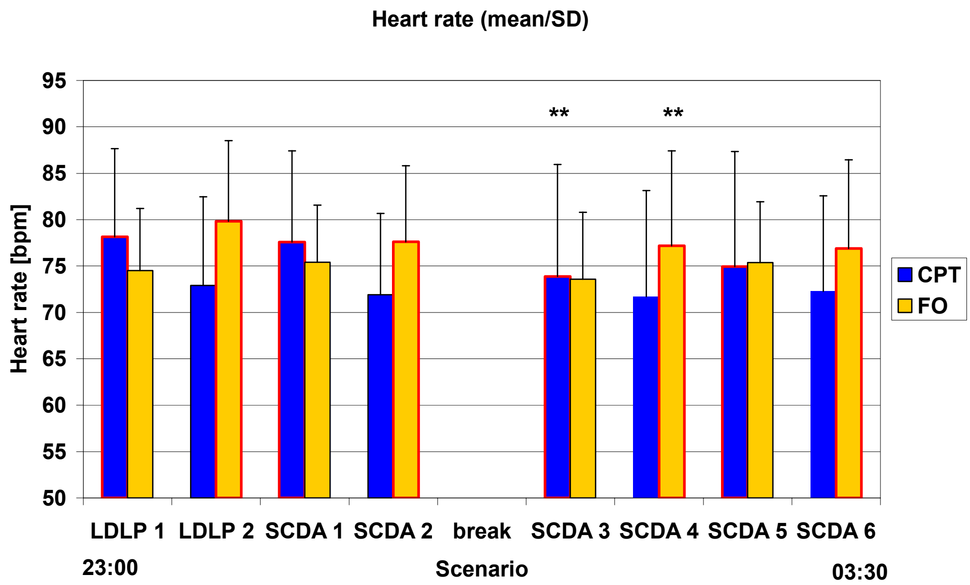

FIG 2. Mean heart rates during the scenarios. ** p<0.01, denote significant differences to LDLP; pilot flying is marked red. LDLP=Low Drag Low Power, SCDA=Segmented Continuous Descent Approach

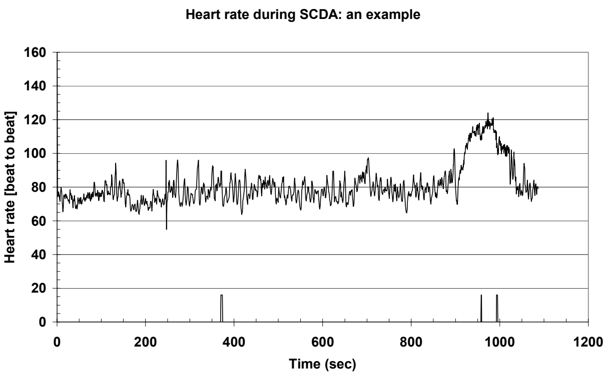

FIG 3. Course of the heart rate during a SCDA of one pilot. Markers above the x-axis indicate beginning of the flight, touch down and stop of the aircraft on the runway.

3.1.2. Blood pressure

Blood pressure was registered once shortly before the first scenario was conducted, and afterwards shortly after the completion of each scenario. Blood pressure values after the SCDA scenarios were rather reduced in comparison to those of the LDLP, though not significantly different. The data recorded before the experiment started were highest.

3.1.3. Cortisol

Saliva cortisol samples were collected once before the experiment started (reference) and then after the finished execution of each scenario. Mean concentrations range from 0.9 to 1.2 ng/ml reaching the lower limits of the normal range for this time of day.

3.2. Psychological data

3.2.1. Task load

Workload was registered using NASA Task load Index [3] ranging from 0 - 300 points (very low – very high task load). SCDA did not result in a higher task load rating than LDLP (Fig 4). As expected, the actively flying pilots had higher task load scores than the non flying pilots ($p=0.002$).

3.2.2. Fatigue

The subjective fatigue was acquired using the Fatigue Checklist according to Samn & Perelli [2] which indicates no fatigue at 0 points and the highest fatigue score at 20 points. The subjects filled in the Checklist once before the study began as reference and thereafter each time the scenarios ended. Fatigue scores differed significantly from reference already after the second scenario and increased throughout the night. Only the break restored the fatigue rating slightly (Fig 5). 91% of the fatigue data ranged in category I and II of the Samn & Perelli scale [2] (sufficiently alert – mild fatigue), only 9% reached category III indicating that “flight duty was permissible though not recommended”.

3.2.3. Acceptance

During the debriefing, pilots were asked about their expert opinion on the procedures. SCDA was rated rather non-problematic, and workload was mainly acceptable. However, they rated the SCDA as being only partly safe in comparison to a LDLP (Fig 6). As a consequence, they emphasized that
(1) further investigations should be conducted, and
(2) a new procedure should be adequately trained.

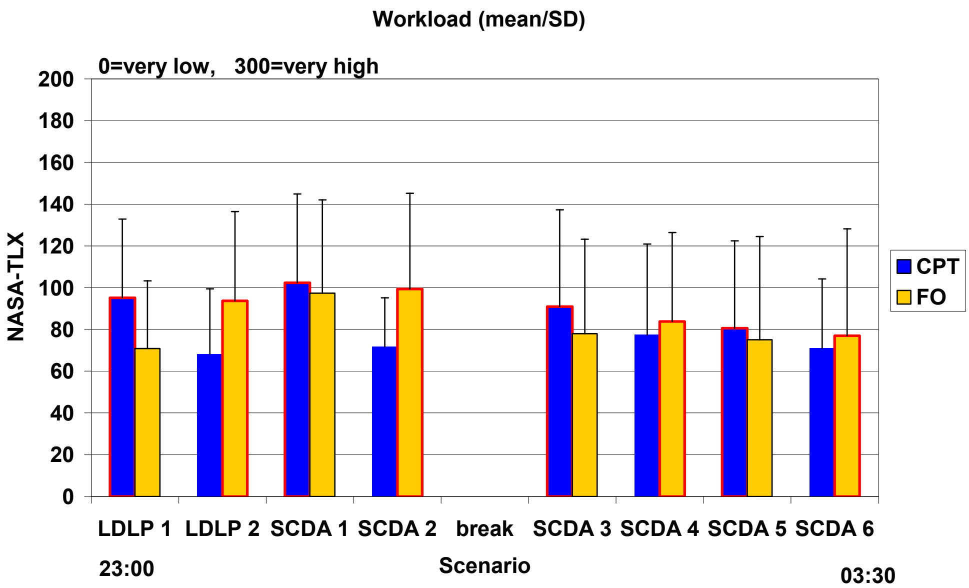

FIG 4. Means of workload registered after each scenario. Pilot flying is marked red. LDLP=Low Drag Low Power, SCDA=Segmented Continuous Descent Approach

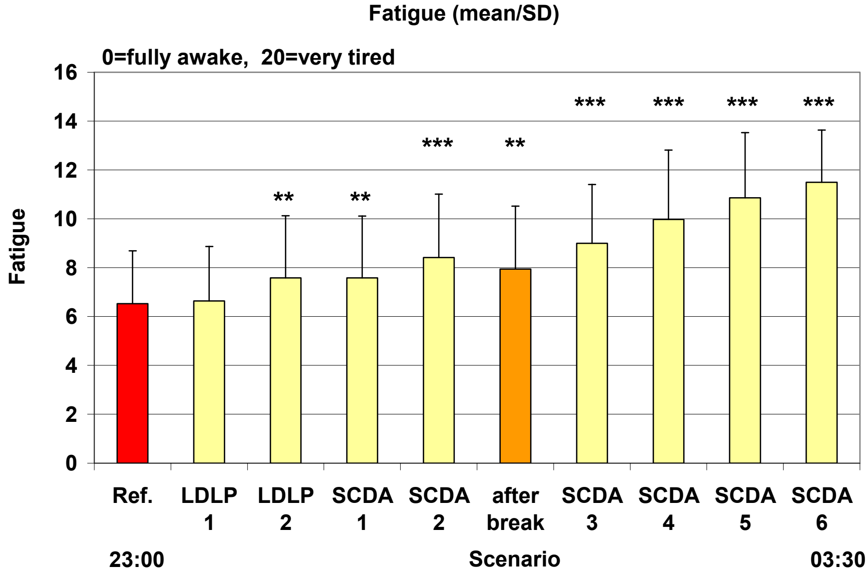

FIG 5. Mean fatigue scores: ** p<0.01, *** p<0.001, denote significant differences to reference. LDLP=Low Drag Low Power, SCDA=Segmented Continuous Descent Approach

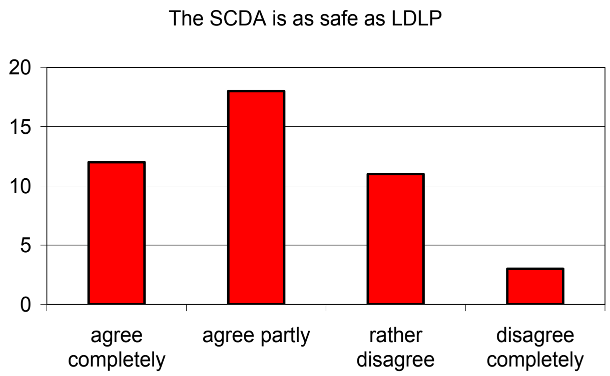

FIG 6. Assessment of pilots (n=40) concerning the safe operability of the SCDA. H. Soll [4]

4. DISCUSSION

The experiments in the two full-flight simulators A320 and A330 have been a first step to investigate noise reduced approach procedures under high fidelity conditions. A new, noise reduced, steep gradient approach (SCDA) was examined in comparison to a standard procedure (LDLP). The investigation of pilot responses to changes in procedures must be carefully observed to assure flight safety. The majority of body and performance measurements, studied in the simulator, did not differentiate between the two approaches. Heart rate, blood pressure and workload were moderately reduced in the course of the experiment, indicating some inner strain at the beginning of the testing. In both approaches, LDLP and SCDA, heart rate showed that the last segment of the scenarios (pivot on the glide slope until stop on the runway) was the most demanding step, the steep gradient segment of the SCDA was far from reaching this level.
Fatigue deepened during the experimental night.

Taking the nighttime into account, increasing sleep deprivation and circadian rhythm factors contributed mainly to the course of the fatigue curve. The increment of fatigue is very well known from other studies conducted during normal passenger operations during night and also from the shift work environment [5-7]. Therefore, it is concluded with respect to fatigue that a difference between the two approaches cannot be clearly proved. However, the acceptance of the SCDA by the pilots was not as good as would be expected. Under real flight conditions, an even worse statement can be predicted. Taking into account the “ideal” study conditions provided in the simulators, such as no ATC-communication, no adverse weather conditions, and no other air traffic, it has to be emphasized that additional investigations are necessary before discussing any application in reality.
One additional important aspect is the potential noise reduction by the SCDA. Further examination of this potential is necessary, since noise reductions may occur at limited areas around the airport, whereas in other areas noise exposure may increase due to the different configuration of the aircraft landing devices.
In conclusion, it is necessary to undertake additional effort for advanced noise reduced approaches. In particular, further studies are strongly recommended which are conducted under real flight conditions.

5. ACKNOWLEDGMENTS

The work was carried out within the research area „Quiet Traffic“ and was funded by the Federal Ministry of Education and Research of Germany. The support of the Ministry is gratefully acknowledged. The authors thank the pilots for their excellent cooperation. Special thanks go to the partners of the collaboration: DLR-Institute of Flight Systems, Lufthansa German Airlines, and Technical University of Berlin, Institute of Aeronautics and Astronautics. The authors thank the Centre for Flight Simulation in Berlin and Lufthansa Flight Training in Frankfurt. Special thanks go to the colleagues of the DLR department Flightphysiology for their support of the study.

6. REFERENCES

[1] U. Isermann (Hrgs.). Leiser Flugverkehr: Zusammenfassender Projektabschlussbericht. Deutsches Zentrum für Luft- und Raumfahrt, Göttingen, 5. Juli 2004

[2] SW Samn, LP Perelli. Estimating Aircrew Fatigue: A Technique with Application to Airlift Operations. Brooks AFB, TX: USAF School of Aerospace Medicine, Technical Report SAM-TR-82-21, 1982

[3] SG Hart, LE Staveland. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In: PA Hancock, N Meshkati (eds): Human Mental Workload. North Holland, Amsterdam, 1988, pp 139 – 183

[4] E-M Elmenhorst, J Heider, RG Huemer, W Jans, R König, O Lehmann, H Maaß, S Nowack, H Neb, G Plath, A Samel, G Saueressig, E Schubert, H Soll, M Vejvoda. Untersuchung der Fliegbarkeit von lärmoptimierten Anflugverfahren durch den Piloten. DLR-Forschungsbericht FB-2005-19, 2005

[5] KE Klein, HM Wegmann. Significance of circadian rhythms in aerospace operations. Neuilly-sur-Seine, France : NATO-AGARD ; AGARDograph Nr. 247, 1980

[6] A. Samel, HM Wegmann, M Vejvoda. Aircrew fatigue in long-haul operations. Accid. Anal. and Prev. 1997, 29(4): 439-452

[7] A Samel, HM Wegmann, M Vejvoda, J Drescher, A Gundel, D Manzey, J Wenzel. Two-crew operations: Stress and fatigue during long-haul night flights. Aviat. Space Environ. Med. 1997, 68: 679-687

7. ABBREVIATIONS

CPT	Captain
FO	First Officer
LDLP	Low Drag Low Power procedure
NASA TLX	NASA Task Load Index
Ref.	Reference
SCDA	Segmented Continuous Descent approach