Applied Acoustics 125 (2017) 194–198

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Noise annoyance caused by continuous descent approaches compared to regular descent procedures

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ARTICLE INFO

Article history:
Received 11 October 2016
Received in revised form 5 April 2017
Accepted 11 April 2017

Keywords:
Continuous descent approach (CDA)
Aircraft noise
Noise annoyance
Virtual reality

ABSTRACT

During Continuous Descent Approaches (CDAs) aircraft glide towards the runway resulting in reduced noise and fuel usage. Here, we investigated whether such landings cause less noise annoyance than a regular stepwise approach. Both landing types were compared in a controlled laboratory setting with a Virtual Community Noise Simulator (VCNS), using four audio samples: an overflight during a regular approach (2000 ft altitude) and three aircraft performing CDAs at respectively 3000, 4000 and 5000 ft. The samples at 2000 ft and 4000 ft were recorded at a countryside road, a 360° photo of which was used for the virtual visuals. The other two CDA samples were derived from the recording at 4000 ft. Participants were asked to rate all flyover samples twice while being immersed in the virtual environment. The CDA at 3000 ft was rated as most annoying, likely due to a longer overflight duration, followed by the regular descent and then the CDAs at 4000 and 5000 ft. As CDAs follow a fairly steady trajectory, it was estimated that they will increase annoyance within an area of approximately 2.5 km^2, as compared to regular landings. Outside of this area, CDAs may instead result in less annoyance than regular landings.

1. Introduction

Aircraft noise can be a burden for communities and individuals living in the vicinity of an airport, especially at night time. As noise annoyance is a key component in airport capacity discussions, any measure to aid noise abatement is welcome.

During regular landing procedures, the aircraft approach the runway in a stepwise manner: alternately descending and flying at steady altitudes depending on e.g. the route, the distance to the runway and traffic situation. To maintain a steady height, extra thrust and therefore more fuel is needed, which in turn leads to extra noise. In the last 15–20 years, many airports worldwide have commenced with using Continuous Descent Approaches (CDAs) in addition to regular procedures. During CDAs, the aircraft stay at their cruising altitude as long as possible [1], and then glide towards the landing strip with an angle of approximately 3° [12] in a vertically optimized route [1]. The amount of drag that is needed to maintain a steady height is reduced in CDAs [10,18] allowing the engines to operate at near idle thrust [1]. Compared to regular landing procedures, a CDA results in reduced fuel burn, lower emissions and noise reduction [5,6,7,8,18,19], until the CDA intercepts the Instrument Landing System (ILS) after which there is no difference between a CDA and a regular landing anymore. In one study, A-weighted peak noise was found to be 3.9–6.5 dB(A) lower at seven locations underneath the flight path. As a 1–3 dB is the Just Noticeable Difference (JND) for noise, this can be called a significant noise reduction. Accordingly, Wubben and Busink [19] reported less noise annoyance around Amsterdam Airport Schiphol after CDAs were introduced at night time. In 2000, it was even suggested that, concerning aircraft noise, CDAs were the most effective noise abatement technique [13].

While previous studies [5,18,19] have consistently shown that both noise and fuel consumption are reduced, no controlled study has, to our knowledge, shown that using CDA procedures leads to a decrease of noise annoyance. With this study, we aimed to compare noise annoyance generated by CDAs and regular landing

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http://dx.doi.org/10.1016/j.apacoust.2017.04.008
0003-682X/

procedures. We hypothesized that annoyance would be lower during CDAs than during regular descent approaches.

For this study, we made use of a Virtual Community Noise Simulator (VCNS). This virtual reality (VR) device allowed us to address noise annoyance by different types of landings in a controlled laboratory environment. Participants experienced flyovers of CDAs at three different heights (resp. 5000, 4000 and 3000 ft), and of regular landings at 2000 ft (the typical altitude which aircraft approaching Amsterdam Airport Schiphol maintain until they intercept the ILS for the final approach (see Fig. 1)). Participants were standing on a virtual quiet countryside road, and were asked to rate their noise annoyance after each flyover.

It was expected that noise annoyance ratings would be lower for all CDA flyovers compared to the regular landing procedures.

2. Methods

2.1. Participants

Twenty-seven healthy volunteers with a mean age of 24.4 years old (SD = 8.8, 11 females) were recruited from the Vrije Universiteit Amsterdam student body, and participated in this study after giving informed consent. Cash money (6 euros) or academic credits were offered as a reward for participation. This study was conducted in accordance with the norms of the Helsinki Declaration.

2.2. Materials

Four one-minute audio samples of descending Airbus 330 (A330) flyovers were used: one regular descent approach at 2000 ft and three CDAs at respectively 3000, 4000 and 5000 ft at the moment of closest vertical proximity to the listener. Both the regular flyover at 2000 ft (before intercepting the Instrument Landing System (ILS)) and the CDA at 4000 ft were recorded in the province of Noord-Holland (near Castricum) in the Netherlands with a Bruel and Kjaer type 4189 microphone. By applying digital signal processing tools, gain and FIR filters [2], that reflect the change in distance, the recorded signal at 4000 ft was made representative for the 3000 ft and 5000 ft flight path. As no change in source noise was applied, all resulting samples contain the same geometric characteristics (directivity and Doppler shift) as the 4000 ft sample. This was done because it was judged that differences due to changes in directivity and Doppler shift would be much smaller than the difference caused by the distance effects. The flyover characteristics are shown in Table 1. In Fig. 2, the loudness curves over time of all overflights are portrayed. All of these samples are representative of procedures that are common for Amsterdam Airport Schiphol (AAS) in the Netherlands.

The Netherlands Aerospace Centre's (NLR's) VCNS [2] was used to create a virtual environment in which the experiment was conducted. The VCNS, a copy of NASA's CNoTE system [16], sends real-time visuals and audio to a Head-Mounted Display (HMD, eMagin Z800 3D visor) and head tracked headphones (Sennheiser EH250), allowing the participant to hear and look around in the virtual environment. Ambient noise was recorded on site and played as background noise to strengthen the immersion. The real-time audio rendering functionality (AuSim's GoldServer, Chapin, 2001) provided real-time binaural effects dependent on the orientation of the participant with respect to the simulated aircraft.

Table 1
A-weighted maximum sound level (LAmax), A-weighted Sound Exposure Level (ASEL) and minimum vertical distance (the shortest distance between the aircraft and the listener during the flyover) of the four audio samples.

Procedure/altitude	LAmax	ASEL	Minimum distance, m
Regular, 2000 ft	70.6	79.3	1033
CDA, 3000 ft	67.6	79.5	1211
CDA, 4000 ft	65.5	77.1	1460
CDA, 5000 ft	63.3	75.2	1727

The virtual visual environment consisted of a 360° photo of the recording site: a small countryside road next to a canal. Both the visuals of the virtual environment and the aircraft were rendered with OpenSceneGraph (OSG, www.openscenegraph.org). The head tracking device on the headphones ensured that the audio and virtual aircraft visuals were in sync.

Measurement of the headphone frequency response using a white noise source, revealed the non-flat behavior of the headphone. The difference with respect to the desired flat response was used to define an FIR-filter ([2], Chapter 5.2). This filter was applied to the audio signals to correct for the non-flat headphone frequency response.

A demographic questionnaire was used to ask specifics such as age, gender, education, hearing proficiency and home environment.

One question (in Dutch) was used to assess annoyance: "Thinking about the last minute, what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by the aircraft noise you just heard?". With this question we stayed as close as possible to the standardized question proposed by Fields et al. [9].

2.3. Procedure

Participants first read an information folder, signed an informed consent and filled out the demographics questionnaire. They were then led into a sound-insulated room where the HMD-visor and headphones were adjusted to fit. A piece of black plastic blocked the peripheral view so the participant could not see the laboratory room.

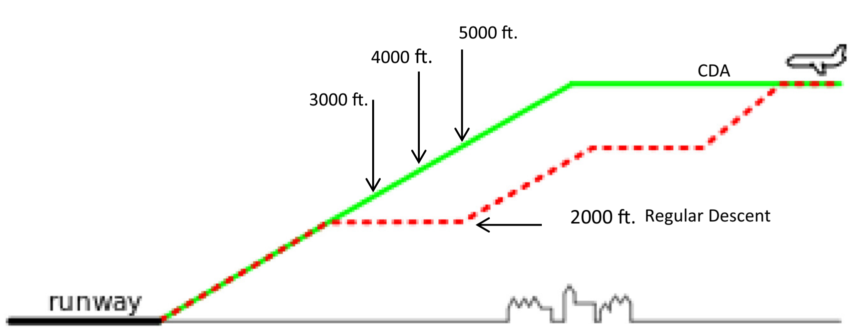

Fig. 1. Flight paths of regular descents and Continuous Descent Approaches (CDAs). Arrows indicate the respective locations of which audio samples were used. Copyright of this schematic profile: Gijs, Wikipedia 2012.