

Sleep quality in Noisy Aircraft Cabins

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ABSTRACT

This exploratory study has investigated the effects of cabin noise on passenger sleep length and quality, because the influence of cabin comfort and particularly cabin noise levels on sleep length and quality is not yet fully understood. Therefore, a feasibility study was conducted to explore the possibilities for a more extensive laboratory sleep study that will be executed later. In this feasibility study two groups of four ‘passengers’ slept under different circumstances. To simulate an immersive experience, these ‘passengers’ were seated on real aircraft chairs and slept in a semi-noise-controlled environment. Each group faced different variances of cabin noise loudness. The effects of these different conditions on sleep length, quality and comfort levels were measured and compared with each other, and with a control condition where subjects slept in their own bed at home. Demographic factors and general sleep quality were gathered to account for individual differences.

The results show that sleeping in the own bed at home is related to better sleep quality and less subsequent fatigue. However, no significant results on sleep and fatigue were found between the different noise conditions.

KEYWORDS

aircraft cabin noise, sleep quality, comfort, fatigue, sleepiness

Introduction

This study investigates sleep comfort in aircraft cabins in relation to experienced noise. Depending on the aircraft type and isolation of the cabin, a different noise level is experienced, which in turn can impact the sleep quality of a passenger. Short term sleep deprivation can lead to different adverse health effects, such as daytime sleepiness, cognitive impairment and gastrointestinal disturbances (Sack, 2010). This study aims to provide insight into the most comfortable noise level for an optimal sleep experience, which may especially be helpful for long-haul flights to reduce fatigue. In turn, airlines and Original Equipment Manufacturers (OEMs) can gain insight into the required noise reduction within cabins to improve passenger sleep quality. Eventually, being able to offer passengers a flight experience with good resting opportunities may be a solid marketing instrument for airlines.

Studies into aircrew (pilots and/or cabin crew) show that they are often subject to high fatigue, due to scheduling and time zone crossings (Sallinen et al., 2020). These high levels of fatigue are, in turn, associated with a higher risk of incidents and accidents (Avers & Johnson, 2011). However, the passengers in the back of the plane may also suffer from fatigue affecting their ability to work or operate a vehicle following a flight. The risks they face may be of another nature than aircrew, but the consequences can also be substantial (Sack, 2010). Thus, it is important to use the knowledge

from other sleep and fatigue research to learn how disturbances and time zone crossings may affect these professionals as well.

Globally, it is estimated that around 20% of all global tourism expenditure in 2021 was business travel related (Statista Research Department, 2023), with Europe ranking as the second region worldwide in terms of business travel (López, 2022). Just before the COVID pandemic hit, the number of outbound business trips in the EU was estimated to be over 37.5 billion (Statista Research Department, 2021). These numbers warrant more research into the consequences of disturbed sleep for passengers.

Aircraft noise, such as that experienced in the vicinity of airports, has a general negative impact on sleep (Basner et al., 2010). Local residents shows a higher probability of awakenings throughout the night with an increase of aircraft noise levels, especially during the most vulnerable stage of sleep. However, the experience of aircraft *cabin* noise differs from aircraft noise as it is a constant noise at a relatively high sound level. Studies show that the continuous noise level (LAeq) during commercial aircraft flights ranges from 69.5 to 74.9 dB(A) for long haul flights (Lee et al., 2022). Continuous noise levels differ per aircraft type. For example, the noise of a Boeing 787 is 72.7 dB(A) and that of an Airbus A320 is 69.5 dB(A). Noise in an aircraft cabin can also be divided in continuous and discontinuous in-cabin noise. Continuous noise levels during cruise flight do not vary much. However, overall noise levels can increase to 81 and even 88 dB(A) when considering instantaneous noise sources, such as mechanical noises for take-off and climb, miscellaneous noises during warning signal, announcements from pilot and flight attendants, and brakes, as measured in an Airbus A321 commercial passenger plane (Ozcan & Nemlioglu, 2006).

Like air quality and humidity, noise in an aircraft is an important variable that has a negative impact on subjective passenger comfort and crew's performance (Mellert et al., 2008; Weber et al., 2004). For example, the study from Pennig et al. (2012) shows that increasing in-flight noise levels resulted in less pleasant and calm feelings in aircraft passengers. Aircraft cabin noise thus can have a negative impact on the comfort of passengers, however its impact on sleep during a long haul flight is not yet clear. This feasibility study was performed to determine all relevant considerations necessary for a study into the effects of different noise levels on sleep quality in aircraft cabins. A higher noise level is expected to be related to lower sleep quality and comfort, more activity during the sleep period, and higher levels of fatigue after sleep.

Method

A laboratory study was executed with a total of 8 subjects. Nine economy class aircraft chairs were placed in a darkened room in three rows of three chairs each. Per test night, four subjects slept in these chairs, each in one "aisle" chair with an empty chair in the middle. The front row was empty. All subjects were employees of NLR.

The experiment was designed as a mixed model with two levels of loudness condition (Loud (L) versus Soft (S)) as between subject factor and two levels of sleep condition (Experimental and Control) as within subject factor. The noise level of condition L was 83dB(A), which is comparable to a louder average noise level, such as an Airbus A350 (Lee et al., 2022). The noise level in condition S was 67dB(A), comparable with an Airbus A380-800 (Lee et al., 2022). For both condition L and S, the sound recording of a Boeing B787 commercial passenger aircraft was used. This sound was recorded on an earlier measurement flight with no passengers onboard. Sounds from other passengers, as well as alerting sounds for the flight crew, or announcement by purser or captain were therefore

not included in this recording. The control condition was a normal sleep measurement at home, and was used as a baseline. Subjects were assigned to one of the two experimental conditions, and were not aware of the noise level they would experience during their simulated flight. A pair of dedicated (tweeter) loudspeakers was mounted around the subjects to produce the noise, and a subwoofer was also placed in the room to support the low-frequencies in the sound.

A scenario of a normal night flight of 10 hours was mimicked. Therefore, subjects were asked to remain in their chairs as they would during a normal flight. They were instructed to behave as they would in an actual aircraft. They reported for the flight at 21:00 where they were briefed and requested to take their seats at 21:30. At 23:00 the light was dimmed and subjects prepared for the night. At 06:30 the light was turned on and at 07:30 subjects were allowed to leave their seats.

Data regarding sleepiness and fatigue were recorded before and 45 minutes after the 'flight'. The Karolinska Sleepiness Scale was used to measure subjective sleepiness (Kaida et al., 2006). Alertness was measured by means of the 3 minute Psychomotor Vigilance Task, an objective measure for fatigue (Basner et al., 2011). To diminish the effects of differences in speed, the morning PVT scores were divided by the preceding evening scores. Furthermore, subjects were asked to rate the quality of their sleep and level of comfort during the night. During the entire simulated flight, subjects' activity level was recorded with an ActiWatch2 activity tracker (Weiss et al., 2010).

Results

The two experimental groups were comparable for gender and mean age. Each group consisted of two male and two female subjects. The mean age of the group in condition L was 37.8 years and condition S 38.3 years. None of the subjects had children under the age of 4, and all considered their health to be at least good. One participant in condition L scored higher than 11 on the Jenkins Sleep Scale, which is indicative of frequent sleep disturbances (Juhola et al., 2021). All other subjects scored lower than 12 on this scale. No significant differences were found between the normal sleep length of the groups in both conditions. However, on the individual strength questionnaire, a significant difference was found on the concentration scale ($t = -1.32, p < .05$), where the S group indicated to have more problems concentrating than the L group (Beurskens et al., 2000).

An independent sample t test showed no significant difference in average noise sensitivity scores between the both groups ($t(6) = -2.38, p = .055$). Even though not significant, a trend was seen where the S group reported slightly higher average noise sensitivity scores ($M = 3.93, SD = 0.76$) than the L group ($M = 2.68, SD = 0.73$). No significant differences were found between the groups on the realistic experience of the simulated aircraft ($t(5) = 2.39, p = .062$).

The data from one subject (L group) were not recorded correctly and were therefore not included in the analysis. The results from the other subjects show that they slept significantly longer in the control condition in the own bed compared to the experimental condition in the aircraft chair ($F(1) = 6.54, p < .05$). No interaction effect was found between the two experimental conditions and the control condition ($F(1) = 1.177, p = .320$). Also, a significant effect was found when focussing on the sleep quality as measured on a 4-point Likert scale ($F(1) = 50, p < .01$), but no interaction effect was visible ($F(1) = .000, p = 1$).

KSS scores measured at least 45 minutes after waking showed no significant differences ($F(1) = 3.191, p = .124$), nor trends between experimental and control conditions ($F(1) = .511, p = .502$).

The reaction times recorded with the PVT were significantly faster after the control condition compared with the experimental conditions ($F(1) = 11.635, p < 0.05$). Furthermore, a trend was found for the interaction between both experimental conditions and the control condition ($F(1) = 3.819, p = .098$), indicating that, contrary to expectations, the S group performed worse after sleeping in an aircraft chair than the L group.

Conclusion and discussion

The results show that indeed sleeping in the own bed at home is related to better sleep quality and less subsequent fatigue. However, no significant results on sleep and fatigue were found between the different noise conditions.

The main goal of this feasibility study was to assess the possibility to conduct a realistic aircraft cabin set up suitable for a simulated night flight. Expectations were met, as 8 test subjects slept in either a louder or quieter sound condition of a simulated Boeing 787. It was expected that both groups would have a longer actual sleep duration (percentage of time spent 'resting') as measured with the ActiWatch during the control condition in the own bed compared to the experimental condition in the aircraft chairs. The results show that the subjects indeed slept significantly longer in the control condition. Additionally, the group that was exposed to loud noise was expected to have a lower sleep duration than the group that was exposed to lower noise levels in the experimental condition. Unexpectedly, no difference between the groups was found.

Furthermore, contrary to expectations, a trend was found where the group in the louder experimental condition showed a faster response time, measured with the PVT than the group in the quieter experimental condition. One possible explanation could be found within the groups. Even though the subjects were divided over the two groups as equally as possible, the results from the baseline questions showed that the group in the quieter experimental condition reported more troubles on concentrating than the group in the louder experimental conditions. Another explanation might be that the S group was slightly more sensitive to higher noise, compared to the L group. Even though this effect was not significant, it should be studied further in the following study.

Since this study was a feasibility study, the number of participants was kept low. Therefore, results should be interpreted cautiously, while focusing on improvements for future sleep studies. A possible improvement is that more instantaneous noise should be added in future studies. This study only presented continuous noise to the subjects and no instantaneous noise, such as pilot and flight attendant announcements that can bring noise levels up to 88 dB(A) (Ozcan & Nemlioglu, 2006), and in turn decrease comfort of passengers (Pennig et al., 2012).

Aside from noise and aircraft seating, no other factors were measured that may impact comfort. For example, subjects commented on the lack of aircraft movement (vibration) during the experiment. The study from Quehl (2001) showed a contribution of approximately 70% of noise and about 30% of vibration magnitude to the comfort assessment in their study. Even though aircraft noise contributes more to the (dis)comfort of subjects, future studies should consider adding vibration. Other factors reported by subjects that may impact the sleep quality include air pressure, humidity, chair position and recline (including the difference between business class and economy class), smaller space surrounding the chairs to mimic the space of an aircraft cabin, and illumination levels.

Overall, this study offers an initial insight in a realistic sleep experience in an aircraft night flight and provides preliminary results on sleep quality and fatigue, as well recommendations for a more realistic study set up with the purpose of an aircraft sleep study.

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