# Comfort in the Regional Aircraft Cabin: Passenger Priorities

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**Abstract.** Regional turboprop passenger aircraft are more fuel efficient than equivalent regional turbofan jets. Aerodynamic interaction between the propeller and the aircraft wing and body cause higher noise and vibration in the turboprop cabin than in jets; to improve the passenger cabin of turboprops, an improve comfort model is required to enable design optimization. Three age-stratified focus groups were conducted with the aim of eliciting passenger priorities for comfort in aircraft cabins. Participants discussed view elicited in response to images of different aircraft, and aircraft interiors. Transcriptions of the focus groups were coded using NVivo and the most common thematic areas identified for each age group. Physical comfort (space and seat design), the physical environment (noise, air quality, vibration, thermal), safety and hygiene were the most commonly coded thematic areas. The oldest group (50–70) rated the thermal environment as more important than younger groups. Turboprop aircraft were considered noisy and to be less comfortable than turbojets. However, noise and vibration were considered to be outside of the passenger's control and therefore accepted.

**Keywords:** Comfort · Aircraft · Passenger · Turboprop · ComfDemo

## 1 Introduction

Passenger aircraft contribute to climate change due to emissions from fossil fuels and the formation of clouds [1]. Long term hybrid and full electrification in aviation will require a move from jet propulsion to propeller aircraft [2]. Even existing turboprop aircraft are generally 10–60% more fuel efficient than equivalent jet turbofan aircraft based on point-to-point analysis [3]. Whilst turboprop aircraft have environmental credentials, their cabin environment is generally considered inferior. This is due to the tonal nature of the noise and vibration, comprising harmonic components due to the interaction of the propeller blade pass and the aircraft wing and body [4].

To optimize the design of future propeller aircraft, an improved understanding of passenger perceptions of aircraft comfort is necessary. This process requires developing a predictive model of overall comfort in the aircraft cabin that is applicable to turboprop designs, and can be used as a starting point for improving turboprop design without the need for real-life test model. A digital twin of the aircraft-passenger system will be developed through the EU ComfDemo project of which this study forms a part.


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This study aimed to gain insight of passenger opinions on turboprops in comparison to jet aircraft and to understand passenger priorities in terms of cabin comfort in regional aircraft.

## 2 Methodology

Three focus groups were conducted with participants recruited into one of three age groups: 18–24 (n = 4), 35–49 (n = 5), 50–70 (n = 5) years old. Each group included male and female subjects. Focus groups were conducted over video conference due to social distancing restrictions during the COVID-19 pandemic. Audio was recorded and transcribed using NVivo, and then coded for analysis.

The focus groups were structured into 4 sections. In Sect. 1, participants were asked to '*write down your initial thoughts, words and associations which come to mind when looking at this image…*'. They were presented with an anonymized black and white image of a Bombardier Dash-8 turboprop aircraft (Fig. 1a). A group discussion led by a facilitator then followed to draw out common themes.


**Fig. 1.** Images of a turboprop aircraft (a) and turbojet aircraft (b) presented in Sects. 1 and 2 of the focus groups. Images were anonymized and presented in black and white.

In Sect. 2, participants were asked the same question as in Sect. 1, but presented with an image of an anonymized black and white image of an Embraer 190 turbojet aircraft (Fig. 1b). A group discussion led by a facilitator then followed to draw out common themes. Participants were given the opportunity to compare their views of both aircraft and able to view both images simultaneously.

In Sect. 3, participants were asked the same question as in Sect. 1/2, but presented with an image of the passenger cabin of a regional aircraft. In the group discussion, they were asked to state what aspects of the cabin environment were important, and what priority needs were in the space.

Section 4 presented 16 attributes previously associated with passenger experience in airline cabins (Table 1). Participants were asked to explain what was particularly important to them in relation to these attributes, and asked which, in their opinion, were the most important and least important attributes.

**Table 1.** Sixteen attributes relating to aircraft cabin comfort presented to participants in Sect. 4 of the focus groups.

| In-flight entertainment | Cabin crew |
|---|---|
| Cabin layout | Food and beverages |
| Seat design | Information and communication |
| Seat spacing | Air quality |
| Luggage storage | Climate |
| Safety | Light |
| Cleanliness | Noise |
| Personal factors | Vibration |

Audio from the focus groups was transcribed and coded to thematic nodes by a single investigator.

The study design was approved by Nottingham Trent University ethical advisory committee.

## 3 Results

From discussions comparing turboprop and jet aircraft, it became apparent that knowledge and experience of turboprop aircraft was not universal amongst groups. There were several comments stating that the turboprop in the image looked older than the turbojet aircraft. Participants across all groups recognized that turboprop aircraft were noisier than jet aircraft, although opinions were broad.

During the thematic analysis on in-cabin comfort, twenty-nine nodes were generated (Table 2). Group 18–35 generated 373 case classifications, 35–49 generated 115, 50–70 generated 492. To give equal weight to each age group, coding counts were normalized by the total number of coded statements within each focus group. Therefore, results were analyzed in terms of the percentage of statements within each of the three age-stratified focus groups.

**Table 2.** 29 nodes generated during thematic analysis of the three focus groups.

| Air quality | Cabin layout | Efficiency | Propulsion – jet | Toilets |
|---|---|---|---|---|
| Aircraft age | Children | Food drink | Propulsion – propellors | Vibration |
| Aircraft appearance | Comfort – experience | Hygiene | Safety | Vision |
| Aircraft range | Comfort – seat design | In flight entertainment | Sleep | WiFi |
| Aircraft speed | Comfort – space | Ingress egress | Storage/luggage | Windows |
| Body size | Crew | Noise | Thermal | |

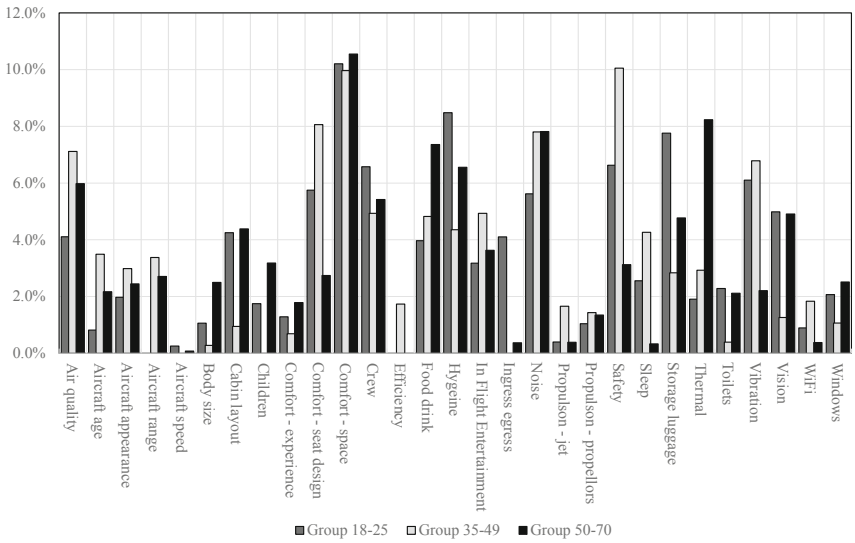


**Fig. 2.** Normalized coding count across the three different focus groups, showing the topics that were most often mentioned during the discussion.

The most commonly coded nodes for the three groups are shown in Table 3. Each node included in the table was ranked in the top 10 for at least one of the focus groups.

The most commonly coded themes were comfort (space), noise and safety. Opinions on space were consistently related to lack of space for the passenger, and the impact of other users' behavior/anthropometry on the subject's personal space (Fig. 2).

Regarding noise, the 18–25 group noted noise from children as a problem; this was not mentioned by other groups. Some participants in the 35–49 group stated that they used noise-cancelling headphones to resolve issues related to cabin noise.

Safety was the most coded theme for the 35–49 group. Despite participants being experienced travelers, many, but not all, expressed ongoing anxiety with safety. This was

considered more acute for turboprop aircraft. The theme was ranked 4th for 18–25 and outside the top 10 for 50–70 group.

Whilst hygiene was considered important, many comments were related to the ongoing COVID-19 pandemic and therefore difficult to separate into short-term and established opinions. However, participants expressed concern over perceived effectiveness of cleaning, and hygiene of headrests and edges of seats used as handholds on either side of the aisle.

**Table 3.** Ranking of most common thematic areas for each of the three focus groups. 1 = the most coded theme. Each theme is ranked in the top 10 for at least one of the three groups.

| Thematic area | Group 18–25 | Group 35–49 | Group 50–70 |
|---|---|---|---|
| Comfort – space | 1 | 2 | 1 |
| Noise | 8 | 4 | 3 |
| Safety | 4 | 1 | 13 |
| Hygiene | 2 | 10 | 5 |
| Air quality | 11 | 5 | 6 |
| Crew | 5 | 8 | 7 |
| Comfort - seat design | 7 | 3 | 14 |
| Food drink | 13 | 9 | 4 |
| Storage luggage | 3 | 16 | 9 |
| Vibration | 6 | 6 | 19 |
| Thermal | 19 | 15 | 2 |
| In flight entertainment | 14 | 7 | 11 |
| Vision | 9 | 21 | 8 |
| Cabin layout | 10 | 23 | 10 |

A range of issues were highlighted under air quality. Several participants discussed issues related to personal hygiene (i.e. odors from other passengers), galley-related odors, toilet smells, and the smell of the apron and jet fuel.

Vibration was discussed in two contexts: aircraft-induced vibration (e.g. from engines and hydraulics) and aerodynamic-induced (e.g. turbulence). Vibration of the aircraft was considered as unavoidable and accepted as part of the flight experience. However, it was still considered as an important contributor to discomfort felt in aircraft.

Thermal issues were frequently coded (ranked 2) for the 50–70 group but were not so often discussed in the other groups. Comments were consistent, that passengers associated in-cabin experiences with getting cold, and that they would take additional clothing for a flight.

## 4 Discussion

The results support and expand on several previous studies. The top listed items here parallel those identified as general priorities for aircraft comfort [5]. Bouwens et al. developed a hierarchy of environmental factors for aircraft comprising, in order, anthropometrics, noise, smell, climate, vibrations, light. The priorities parallel with the order in which the items appeared in this study (Table 3).

Vanacore et al. has previously shown that there are differences in perceived aircraft seating comfort with age [6]. This study indicated that some factors (e.g. thermal) are more important for older passengers, and others are less important (e.g. safety). With an ageing population it is therefore necessary to consider the needs of older travelers in climate design.

Studies on scent in aircraft [7] have shown that addition of odors designed to improve the passenger environment have a complex association with comfort; the importance of unpleasant smells is illustrated in this study as being high. It appears that there is scope to design aircraft-specific masking scents to improve the perceived cabin environment.

Turboprop aircraft were considered noisy and to be less comfortable than turbojet aircraft. The priorities related to cabin environments reinforced the priorities in designing turboprop aircraft cabin environments, and highlighted that there is a need to prioritize the physical ergonomics including the space and seat design, and the environmental features including noise, vibration and thermal elements. As the noise and vibration environment in turboprop aircraft is different to that experience in turbojets [4], there is a need for specific research to understand the human response to the multi-factorial environmental attributes.

## 5 Conclusion

The study investigated passenger travel comfort opinions in turboprop and jet aircraft. Individual space was the most commonly coded theme during the focus groups. The 50–70 group spoke more about the thermal environment than other groups; 35–49 spoke more about safety than other groups. Noise and vibration were both considered important but somewhat out of the passengers' control and accepted.

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