The environmental comfort experience and activities of flight attendants in a turboprop airplane

The aviation industry needs to reduce CO_2 emissions. Turboprop aircrafts consume 10-60% less fuel compared to regional jets. In addition, electric propeller aircrafts are now in development, which can be CO_2 neutral. However, in turboprop aircrafts the noise level is high and the space is limited. For flight attendants that work long hours in these aircrafts, this could become demanding. In this paper, the environmental comfort and ergonomics are studied in an experiment in a turboprop aircraft as a base for improving the working conditions for cabin personnel in future propeller aircrafts.

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The turboprop airplane in which flight attendant research is done.

This research is part of the EU-funded ComfDemo project, which focuses on studying factors influencing the passenger comfort in a propeller driven aircraft. Data of different factors influencing comfort are collected for building a demonstrator that simulates future propeller aircrafts with less or even no CO_2 emissions. In this demonstrator, the effects of different environmental characteristics can be simulated and the effects of these characteristics can be tested with humans. Although the main focus of the project is on passenger comfort, an additional aim was to gain insight in flight attendants' (FAs') activities and their environmental comfort experience, as comfort might increase the positive emotion of FAs, subsequently might have a positive influence on the passengers.

Much research has been done on health and safety of cabin crew members. Griffiths and Powel (2012) provided examples of important factors, such as radiation exposure, cancer, mental ill-health, musculoskeletal injury, reproductive disorders, and symptoms from cabin air contamination. Much less research has been done on the comfort experience of FAs. Some cabin crew comfort factors are similar to those for passengers, such as air quality and noise. However, many also differ considerably due to the tasks the crew performs. Comfort aspects of cabin interiors relevant for crew members are described in the Clean Sky deliverable Key Cabin Drivers for Passenger/Cabin Crew Comfort and shown in table 1 (on page 8).

Most problems of the FAs are linked to air quality and noise, to the lifting of hand luggage and handling the trolleys and in the aisle. Agampodi et al. (2009) showed that the leading causes of musculoskeletal problems were pulling, pushing or lifting. The commonest type of injuries were strains and sprains. Other aspects were

turbulence-related injuries with upper limbs and the back as the commonest sites affected. Lee et al. (2008) focused on psychological risk factors and showed that high job insecurity significantly increased the risk of lower-back work-related musculoskeletal disorders for female FAs. Glitsch et al. (2007) showed that pulling the trolleys forced the FAs to adopt ergonomically unfavourable postures such as pronounced flexion of the back, particularly among female subjects. More in detail, this was assessed by observation of trolley handling on planes and by physical workload analyses of pushing and pulling of trolleys in a laboratory set up. The greatest physical workload is to be expected at the beginning of service when trolleys are fully loaded and the cabin floor is inclined (even up to 8°), as the aircraft is still climbing, particularly on short-distance flights when the galley is in the back of the airplane. The posture analysis demonstrated that pulling forced the FAs to adopt ergonomically unfavourable postures such as pronounced flexion of the back, particularly among female subjects.
Effects of noise and vibration were studied by Mellert et al. (2008). Noise and vibration affect FAs in the cabin and pilots in the cockpit, besides numerous other physical environmental parameters, e.g. air quality, draft, temperature distribution, humidity and glare. Additionally, the physiological setting and psychological attitude modulate the impact of environmental parameters. The sound level is an important parameter besides air quality with a negative impact on subjective feelings and significant bias on the crew's performance, in particular during long-haul flights.
In summary, a diverse set of aspects related to occupational safety and health (OSH) for FAs, both physical and psychosocial, have been reported. However, most studies concern jet aircraft and not much is known on turboprops, while this is relevant as more propeller propulsion might be introduced in future. Therefore, the research question for this paper is: what is the environmental comfort experience and what are the activities of flight attendants in a turboprop airplane.

Method

To answer the research question, data were collected during two flights with a commercial turbo airplane.

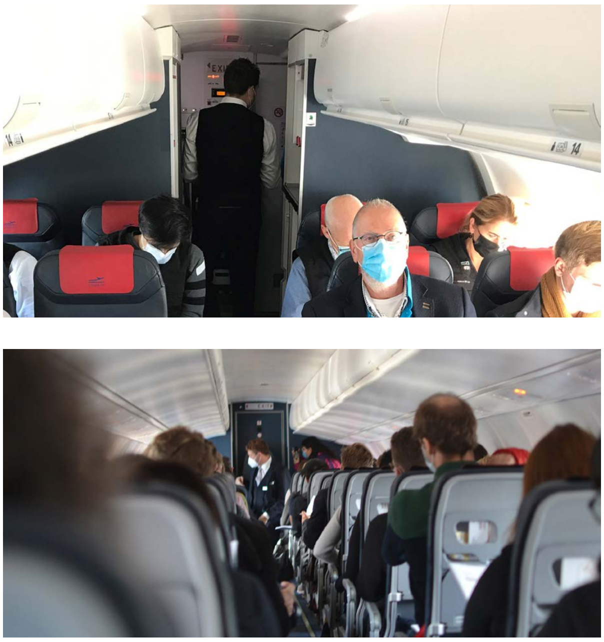

Figure 1. The interior of the ATR72. Left: the FA in the galley in the back of the airplane. Right: the FA in the front of the airplane on the FA seat.

The first flight contained fifty-two passengers, the second flight forty-five passengers. In each flight eight researchers, two pilots and two FAs were on board. The seventy-minute flight took place in an airplane (type ATR72) with a start and end at Rotterdam The Hague Airport, The Netherlands (see figure 1).

The flights were considered as regular flights with the following phases:

1. Preparations.
2. Boarding.
3. Taxiing & Take-off/climbing.
4. Cruising.
5. Descending & Taxiing.
6. Deboarding.
7. Cleaning.

The passengers were allowed, when the safety sign was off, to walk through the airplane for instance to go to the toilet. During each flight two FAs were active, supporting the passengers. The passengers were served drinks and food in their seats by the FA(s).
For each flight, one FA was followed by a researcher(s) to observe his/her activities. The observation was done

Table 1. Technology challenges of different types of users regarding cabin interiors (adapted from AIR-ALA-DEL(D-B-4.4.1)-0001, 2018.

	Technological challenges			
Cabin interiors major item	**Crew living space and accessibility**	**Crew thermal comfort**	**Crew noise/ vibration reduction**	**Crew comfort**
Cabin lining	x	x	x	
Thermal/Acoustical insulation		x	x	
Flight attendant seat	x		x	x
Kitchen	x	x	x	x
Stowage bin	x		x	x
Lavatory	x		x	x

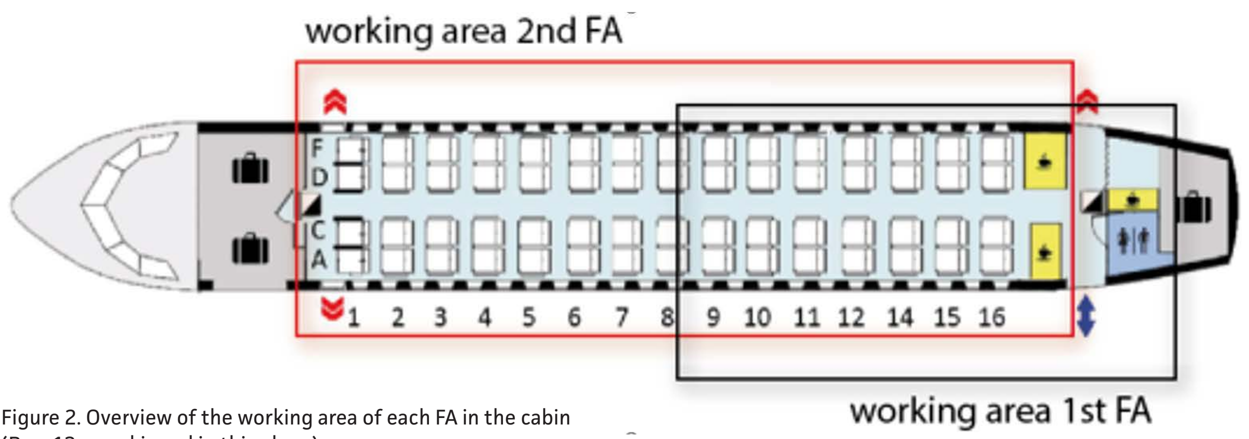

Figure 2. Overview of the working area of each FA in the cabin (Row 13 was skipped in this plane).

during the whole flight, including the phases boarding, taxiing & take-off/climbing, cruising, descending & taxiing, and deboarding. Preparation and cleaning tasks were discussed in the interview but not quantitively measured. During the first flight, the FA with the main focus on the aisle and the kitchen at the back of the airplane was studied. During the second flight, the FA with the main focus at the front passengers was studied. The working areas for the two FAs are shown in figure 2. The frequency and duration of activities were recorded by an android phone (6.0.1 Moto X Play) using a task-time measurement app, containing the following predefined activities:

1. Sitting: recorded if the flight attendant sits down for more than 30 sec.
2. Standing: the flight attendant is at one place for longer than 30 sec.
3. Walking: (the flight attendant is moving around in the plane.
4. Work in aisle: the flight attendant is assisting the passengers.
5. Move trolley: the flight attendant is moving or manoeuvring the trolley.
6. Work in the kitchen: the flight attendant is preparing the food and drinks before it can be handed out.
7. Serving: the flight attendant is handing out food and drink to passengers during the flight.
8. Personal care: going to the toilet, clothing and hair care.

The forces needed to move equipment of the FAs were recorded as well in the gallery and the aisle (equipment was a Push Pull gauge (type: AFG2500N-MK2) and ergonomically relevant dimensions of the trolley were measured using a tape measure. Temperature was recorded at different heights at different phases in the flight (0.1, 0.5m and 1.1 m from the floor) by a MSR145 temperature Data Logger (Range: +5 to +45 °C with accuracy of ±0.1 °C). During the second flight the Sound Pressure Level (SPL) in dB(A) was measured during cruise flight at each seat row in the aisle and galley with a B&K® 2270 Sound Level Meter.

A structured interview after the first flight was conducted with both FAs at the same time. This interview focused on the comfort experience during their flights, addressing different aspects such as physical workloads, thermal environment, air quality, vibrations, body discomfort, light, acoustics and overall health and mood. In the interview the FAs could give their opinion on aspects they brought forward.

Results

Usually, the FAs switch their roles after a flight. However, during this investigation, the FA kept their role (and therefore their working area) the same. Table 2 shows the duration of the flight phases. The time per phase was determined on the basis of the activities of the FA. Figure 3 shows the percentage of time spend on the various activities during the flight, including boarding and deboarding. The second FA spend more time sitting, probably due to the longer taxi and take-off phase of the second flight.

Table 2. Durations of the flight phases.

Flight phases	Duration phases first flight	Duration phases second flight
Boarding	00:22:25	00:20:03
Taxi & take-off/ climbing	00:08:34	00:16:40
Cruising	00:50:07	00:41:45
Descending & taxi	00:17:04	00:17:51
Deboarding	00:11:19	00:05:14
Total	01:49:29	01:41:33

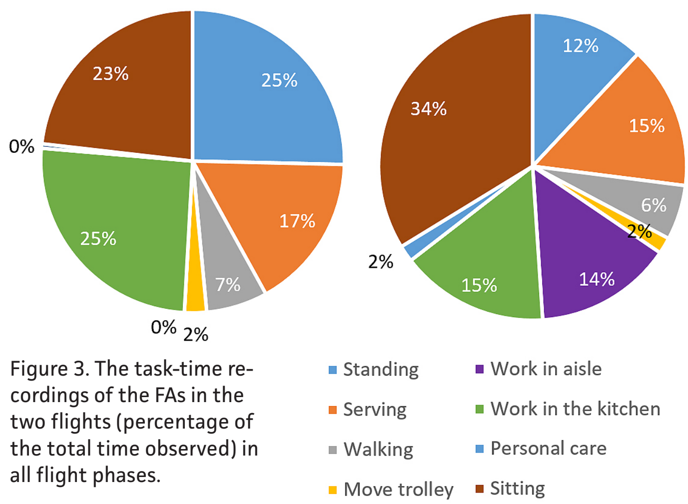

Figure 3. The task-time recordings of the FAs in the two flights (percentage of the total time observed) in all flight phases.

The first FA spends more time in the kitchen, preparing the trolley before serving. While serving, the trolley is heavily used. FAs frequently move the trolley and stop it for serving food and drinks, and drawers in the trolley are frequently opened and closed as well. For moving/ stopping the trolley, the FA(s) has to deal with starting forces, to move and manoeuvre the trolley. In addition, unfavourable working postures are frequently required. Figure 4 presents the size of the trolley and the FA in a forward-flexed posture for serving passengers.
During a normal flight the two FAs use a total of seven trolleys: two with drinks, three with food, one with spare tea, glasses and cups and one with spare drinks. The average force to pull a trolley in the aisle is 27.1N. The trolley has a maximum estimated weight of 60 kg (the heaviest trolley is with the drinks). This is the trolley that is used most frequently during flights. The pushing/ pulling force to move the trolley over floor threshold is 119.6N. This physical strain is rather large, but acceptable according to the guidelines for pushing forces in moving loads while walking (NEN 2738:1991). In these flights a total of two trolleys were used to serve the passengers and on average each trolley was moved eight times per hour. However, four other trolleys also had to be moved in the kitchen to supply these two trolleys.

FAs spent 15-25% of the task-time in the kitchen. The two working areas in the kitchen, where most activities are conducted are 1080 mm from the ground and 1100 mm from the ground. Regarding the NPR 1813 (a Dutch ergonomics guideline) this is a good fixed working height. In the kitchen the working area is 750-860 mm in fore-aft space and 1680 mm left-right space at eye height. The limited space and the tasks of the FAs affect the posture. For instance, FAs sometimes worked above shoulder height to get cups, food or drinks from the high cabinets

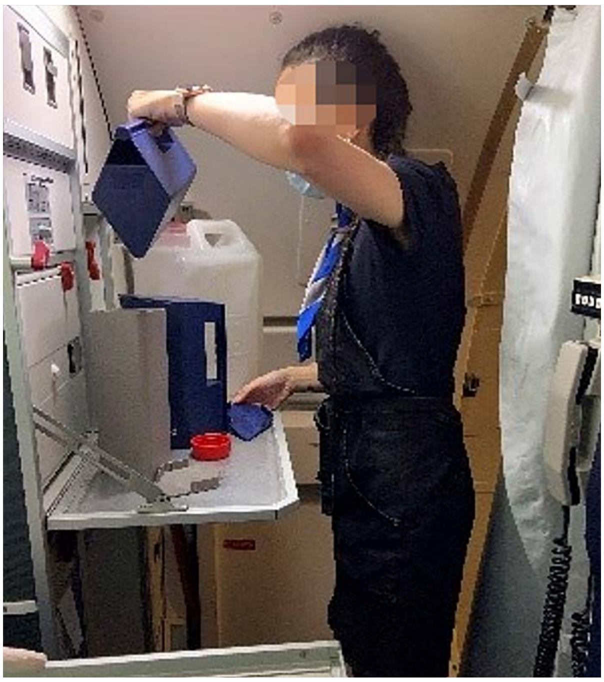

Figure 5. The FA pouring coffee in the kitchen.

Figure 4 Figure 4: Dimensions of the trolley (right) and a FA with a forward flexed posture (above).

and had to manoeuvre the trolley around in the kitchen. Figure 5 presents the activity when the FA had to pour the leftover coffee into a jerrycan. This posture lasted for more than 2 minutes during which the FA worked above shoulder height consecutively. According to ISO standard 1005, it is not allowed to work above shoulder height for more than two minutes consecutively with a static posture.
The lowest temperature is recorded at the feet level (between 11 and 19.5 degrees on the first flight and between 19.5 and 21.5 degrees in the second flight; 0.1 m from the floor) and the highest is at head level of a seated passenger (between 17.5 and 24 degrees in the first flight and between 22.5 and 24 degrees in the second flight; at 1.1 m from the floor). Temperatures in the first flight were lower as it was the first flight of the aircraft in a cold November morning. The temperature in the cabin increased to more comfortable levels during the flight.
A peak noise of 89 dB(A) was measured during take-off. In the cruising phase, the noise level is different throughout the cabin as is shown in figure 6. The noise in the middle of the cabin (approximately 82.5 dB(A)) was highest as it is closest to the propeller. In the galley, the noise level is high as well (82.2 dB(A)).
In the interview, the FAs reported extreme discomfort in the arm, shoulder, neck and back when lifting the trolley over the floor thresholds. Heavy physical strain was also mentioned during the cleaning of the airplane. To clean the airplane, a lot of bending is required. The FAs reported extreme discomfort of their back during the cleaning activities. Cleaning the airplane follows immediately after the flight, because the aircraft has to take off again as soon as possible.
One FA experienced the temperature of the first flight as neutral and the other as hot, probably because of the

number of physically demanding activities. The FAs experienced the light in the environment as good. The FAs also reported in the interview that they experienced much noise in the front and at the back of the airplane. The kitchen in the back of the cabin seems especially noisy, but the measurements do not support the perceived high noise levels in the front of the cabin.
The FA reported that this test flight somewhat differed from regular flights. There was much more movement in the airplane due to the activities of the research crew. Therefore, the trolley had to be moved more than during normal flights.
The FAs sit 23-34% of the time which is unexpectedly experienced as a quite heavy mental load, as they are required to actively monitor the passengers. Overall, the FAs have little rest during the flight.

Discussion

For future propeller airplanes, most attention should be given to the physical environment and the noise. Temperature issues were also reported, but in modern aircrafts, FAs can regulate the temperature. For increased comfort, it is advised to use floor heating systems that increase the temperature at feet level.
The activities most observed are sitting and working in the kitchen. While sitting is providing physical resting time, the crew remains alert and observes the passengers for safety reasons. Work in the kitchen is hampered by the limited space available. Ergonomically, work is organised according to standards, except when left-over coffee has to be emptied into a jerry can. Working with the trolley is also found physically demanding, but it does not exceed the European guidelines for pushing. However, Schaub et al. (2007) showed that especially for higher floor inclinations and high weights, flight attendants work above recommended limits with trolleys. In our turboprop flight, the altitude was 17,000 feet which is relatively low, which means a shorter climbing phase and it was possible to use the trolley after the climbing phase in our case. Also, Glitsch et al. (2007) showed that pulling forced flight attendants to adopt ergonomically unfavourable postures such as pronounced flexion of the back. FAs are likely to physically overload themselves if they frequently have to move heavy trolleys on an inclined cabin floor.
The noise in the cabin needs attention. According to the Dutch working conditions law (arbowet) exposure to a daily dose above 80 dB(A) must be avoided, and the employer must provide hearing protection. This measured noise issue is in line with other studies on turboprop airplanes (e.g. Mansfield et al., 2021; Vink et al., 2022). Cabin noise can increase the awareness of symptoms such as swollen feet and headache (Mellert et al., 2008), but can also cause differences in comfort experience and mood (Pennig et al., 2012). Therefore, for future propeller aircrafts it might be wise to look at noise reduction systems or develop electric propellers with reduced noise.
This study was done with a limited number of FAs and though the flights were considered as regular flights, the research activities conducted may have affected the activities of the FAs. Due to the activities of the researchers, more trolley handlings were required than normal. On the other side, the measurements are in line with the perceptions of the FAs. Because the noise recordings and recordings of space and postures are very similar to regular flights, this study provides a reliable and unique estimate of the activities and workload of the FAs in a turboprop.

Conclusion

In general, it can be concluded that the tasks of the FAs in a turboprop are challenging regarding both physical and mental aspects. Unfavourable postures, high forces required for manoeuvring the trolley, little recovery time and a noisy environment all contribute to increased physical workload levels, which cause discomfort. The work is mentally demanding as resting time is very limited on short flights. When developing aircraft interiors, attention should be paid to reduce cabin noise and to ergonomic designs that require lower physical forces and allow FAs to work with healthy postures.

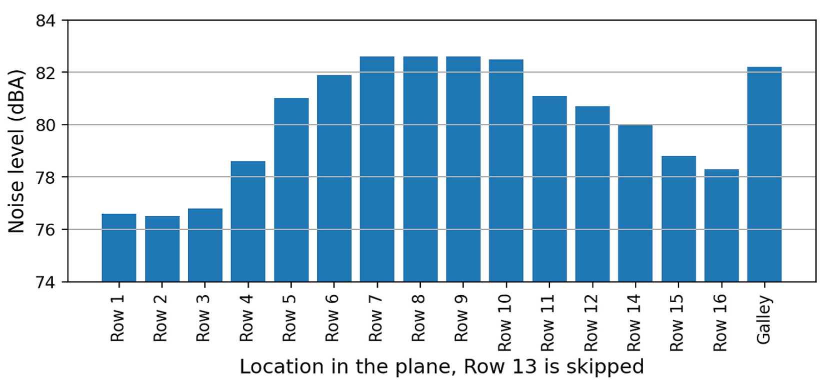

Figure 6. The recorded noise levels (in dB(A)) of different rows and the galley (Müller et al., 2022). Measured in the aisle at the height of just above the headrest of the seat. Row 1 is in the front of the airplane, row 16 is the last row and the galley is at the end of the cabin (measured at the same height).

Evaluation of this study on human factors criteria

The systems approach can be seen in this paper as not only the physical aspects like lifting the cans get attention, but also socio-technical and organisational aspects are studied. Work stress factors are studied. For instance, in the total workday of a flight attendant, they also have moments of sitting, but then they cannot rest as they have to check what the passengers do while seated.
This study is not design driven as it is a study of the current situation and this is input for a next phase: the design of future airplanes with propeller propulsion.
Well-being and system performance are taken into consideration. Well-

being is explicitly asked in the interviews and the study is done within the context of future flying with electrical or hydrogen powered airplanes, which perform fuel efficient with less or no carbon emission.

Acknowledgement

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Samenvatting

De luchtvaart is bezig de CO_2-uitstoot te beperken. Turbopropvliegtuigen kunnen daarbij helpen, omdat ze 10-60% minder kerosine verbruiken. Daarnaast zijn er nu elektrische vliegtuigen en waterstofvliegtuigen in ontwikkeling, die vaak propellers hebben. Propellers zijn efficiënt, maar hebben het nadeel dat er relatief veel geluid in de cabine waarneembaar is. In dit artikel is de belasting op stewards en stewardessen in een turbopropvliegtuig vastgelegd om in de toekomst propellervliegtuigen beter te kunnen ontwerpen.
De belangrijkste uitkomsten zijn dat stewards en stewardessen behoorlijk mentaal en fysiek belast worden in de turboprop. Bij het manoeuvreren van de trolley komen ongunstige houdingen en hoge krachtsinspanningen voor en het geluidsniveau is bij een achturige werkdag te hoog (boven de 80dB). Voor toekomstige propellervliegtuigen is aandacht om het geluid te verminderen en aandacht voor de fysieke belasting nodig, bijvoorbeeld om het vliegtuig zonder fysieke drempels te ontwerpen.

Relevance

This study concerns the activities and load of flight attendants on a turboprop flight. This can be used as a base for improving the working conditions for cabin personnel in future propeller aircrafts. There will be a revival of the propeller aircraft as it is fuel efficient and many future electric aircrafts will have propellers.

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