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Vink, Peter; Anjani, Shabila; Percuoco, Chiara; Vos, Roelof; Vanacore, Amalia

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A Staggered Seat is Beneficial for the Flying V Aircraft

Peter Vink[1(✉)], Shabila Anjani[1], Chiara Percuoco[2], Roelof Vos[3], and Amalia Vanacore[2]

[1] Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands
P.Vink@tudelft.nl
[2] Department of Industrial Engineering, University of Naples Federico II, 80125 Naples, Italy
[3] Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

Abstract. Staggered seats might be a solution for a V-shaped aircraft (the Flying V). The cabin longitudinal axis of this airplane has a 26° angle with respect to the direction of flight. When seats are positioned in the direction of flight, they consequently have an angle to the cabin and become staggered. It is unknown whether the comfort of this staggered seat is appreciated. In this study, 117 participants tested the comfort and the privacy experience in this staggered seat compared with a regular aircraft seat. The experiment showed that both comfort and privacy were significantly better in the staggered seats. However, the analysis is based on short-term evaluations, which means that long-term effects still need to be studied and also the effects of groups travelling together need to be investigated.

Keywords: Aircraft seat · Staggered · Comfort · Flying V · Leg room · Arm Rest

1 Introduction

1.1 A New Aircraft: The Flying V

Flying V is a new type of long-haul aircraft under development (Fig. 1), whose form will allow a reduction of 20% in energy consumption due to its unique shape (Vink et al. 2020). The Flying V does not consist of a traditionally configured circular fuselage with a set of wings, but the passenger cabin, cargo hold and fuel tanks are integrated in the wing structure of the Flying V. At the moment, the Flying V is designed to use traditional kerosene engines, but also carbon neutral ways of propulsion, like hydrogen or synthetic kerosene, are under study.

1.2 Staggered Seats

The wings of the Flying V have an angle of 26° with respect to the direction of flight, which means that the cabin (integrated in the wing structure) has this angle as well. As a consequence traditional seats placed in the direction of the cabin, would also have such an angle with respect to the direction of flight. Because of crashworthiness,

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Fig. 1. An impression of the Flying V that is under development.

safety regulations do not allow an angle of more than 18° from the direction of flight (Humm et al. 2016), for this reason, a staggered seat placed in the direction of flying was considered for the Flying V. This means that the seat has an angle of 26° with respect to the cabin and the adjacent seat closer to the center of the airplane is slightly set back (Fig. 2); the front of the seat can be flipped up to enable in- and egress (Fig. 3).

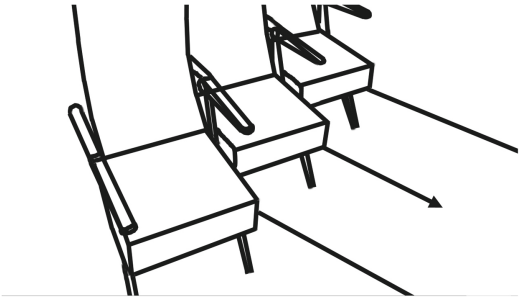

Fig. 2. Staggered seats of the Flying V. The arrow is the direction of the cabin in the wing and the seats are in the direction of flight and angled with respect to the cabin.

Fig. 3. To allow in- and egress and variation in posture the seat has the possibility of flipping up the front part of the seat.

The Rebel company had these seats available and adapted them for the Flying V. A 1:1 mock-up (6 m wide, 2.1 m high and 6 m long) of a cross section of the Flying V cabin was made and two rows of four staggered seats were placed in it.

Moving from the idea that the understanding of passenger comfort experience and its implications for the design of the aircraft interior is becoming a competitive edge in the aerospace industry, the research question is to investigate how Flying V staggered seats are perceived from potential passengers in terms of comfort. The comfort analysis includes also an investigation on the experience of privacy and control when potential passengers are seated in the aircraft, because this is an important factor in determining the overall comfort experience (Ahmadpour et al. 2016).

2 Overview of Comfort Study

An explorative study, involving 117 participants, was carried out to investigate the seating experience of new staggered seats (the Flying V seats) compared with regular aircraft seats, in terms of comfort and privacy. All participants tested in a random order both seats in the same conditions. In the first comfort test, each participant sat in the second row of the tested seats (regular or staggered); for the first 5 min the participant was free to choose to perform an activity (i.e. reading a magazine, talking to their neighbor or using his/her smart phone); in the last 5 min, he/she had to complete an online questionnaire with his/her mobile phone. The online questionnaire was accessible by scanning a QR code located at the back of the seat in front of the participant.

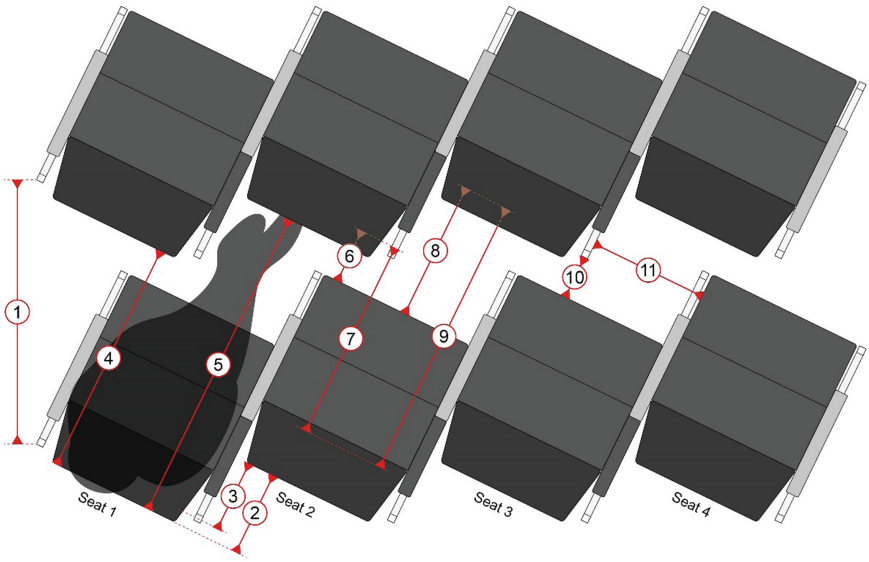

Fig. 4. Top view of the dimensions of the staggered seats. 1 = 79 cm (31″ pitch); 2 = 24 cm; 3 = 18 cm; 4 = 71 cm; 5 = 94 cm; 6 = 27 cm; 7 = 68 cm; 8 = 52 cm; 9 = 92 cm; 10 = 17 cm; 11 = 31 cm.

At the end of the first comfort test, participant moved to the other seat to be tested (e.g. the regular if he/she had tested the staggered and vice-versa), he/she repeated the comfort test, by performing the same activity and then completed the questionnaire.

The two seats analyzed were positioned at 31″ pitch, the regular aircraft seats were 18″ wide, the staggered ones were 17.8″ wide. It is worth pointing out that, the pitch of these seats is not comparable (Fig. 4 and Fig. 5) due to the 26° angle with respect to the flying direction of Flying V. Participants rated the overall seat comfort as well as the comfort of specific seat features using a 10-point Likert scale (1 = no comfort; 10 = extreme comfort) and the same scale was adopted to rate his/her privacy experience (1 = no privacy; 10 = extreme privacy).

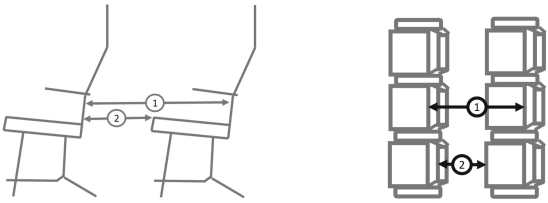

Fig. 5. Dimensions of the regular aircraft seat. 1 = 79 cm (31″ pitch); 2 = 35 cm.

2.1 Statistical Data Analysis

Data analysis was aimed at comparing the comfort and privacy experienced by participants when testing the regular seat and the staggered seat. The Wilcoxon signed rank test was applied to assess the significance of differences in perceived comfort between the two seats under study.

A cumulative logit model (CLM; McCullagh 1980) was applied in order to investigate whether differences in overall comfort ratings could be related to passenger characteristics and/or seat comfort features. The CLM is probably one of the most well-known regression models for ordinal data (Agresti 2010) and it can be properly adopted to model subjective comfort data that fall in an ordered finite set of categories.

3 Results

The main anthropometric characteristics of the 117 participants involved in the study are reported in Table 1.

For both staggered and regular seat, the median comfort score was 7 and the median absolute deviation (MAD) was 1. The Wilcoxon signed rank test did not show a significant difference in overall comfort between the staggered and regular seat, nevertheless the scores obtained by the staggered seat were significantly higher than the ones obtained by the regular seat for the comfort of the armrest ($pvalue = 5.33 \cdot 10^{-7}$), the comfort of the seat pan behind the knees ($pvalue = 0.013$) and the comfort at the upper part of the backrest ($pvalue = 0.012$). For the question 'do you have enough privacy?' (1 = no privacy; 10 = extreme privacy), the staggered seat obtained scores that were significantly

Table 1. Main anthropometric characteristics in terms of mean, (standard deviation), [min -max].

	Num	Age [years]	Height [cm]	Weight [kg]
Female	58	30 (18.17) [11–70]	166.4 (22.2) [153–184]	65.4 (12.3) [36–94]
Male	59	33.7 (18.6) [11–71]	180.5 (10.8) [146–205]	75.3 (14.9) [38–116]

higher ($pvalue = 0.0045$) than the regular seat with median scores equal to 6 (MAD = 2) and 5 (MAD = 2), respectively.

The explanatory variables included in the two CLMs fitted to explain the overall comfort of the two seats under study are 4 anthropometrical descriptors (age, x_1; gender, x_2; height, x_3; weight, x_4) and 5 specific seat comfort features (comfort of the armrest, x_5; comfort of the backrest in the upper part, x_6; comfort of the backrest in the lower part, x_7; comfort of seat pan, x_8; comfort of seat pan behind the knees, x_9). In order to improve model interpretability, the 5 variables related to specific seat comfort features were transformed into dichotomous variables taking the value 7 as a cut-off point for assuming a good comfort perception. The estimates for the CLM parameters are reported in Table 2.

Table 2. Significant CLM parameters for staggered and regular seat.

Staggered seat				Regular seat			
Parameter	Estimate	Standard error	p-value	Parameter	Estimate	Standard error	p-value
$ß_2$	1.17	0.344	0.0006	$ß_6$	0.77	0.407	0.06
$ß_9$	0.659	0.339	0.052	$ß_7$	1.083	0.406	0.008

The significant variables are not the same in the two models: gender (x_2) and perceived comfort of the seat pan behind the knees (x_9) were significant for the staggered seat; whereas perceived comfort in the upper and lower part of the backrest (x_6, x_7) were significant for the regular seat.

Interpretation of the CLM parameter estimates by odds ratios provides interesting information. For the staggered seat, a high overall comfort evaluation is 3.2 times more likely for female participants than for males; participants with a good comfort perception of the seat pan behind knees are 1.9 times more likely to assign higher overall seat comfort score. For the regular seat, participants with a good comfort perception at the upper and lower part of the backrest are respectively 2.2 and 3 times more likely to assign a higher overall seat comfort score.

4 Discussion

The staggered aircraft seats of the Flying V that fulfill safety regulations seem promising. The comfort and privacy experience are both evaluated better. Probably the fact that each passenger has its own space on the armrest and the fact that there is more shoulder space because the shoulders are not exactly next to each other (Fig. 6) contributes to the positive comfort experience. This influence was affirmed in a previous study (Vink et al. 2020), though in that study participants mentioned more complaints like that the seat was hard and that the backrest angle should be more backwards. Some participants also mentioned that the arm rest is of hard plastic.

The comfort score for the regular seat in this study is comparable to the results of the study of Anjani et al. (2020), who reported around 6 for 30″ pitch and around 7 for a 32″ pitch. The comfort score for the staggered seats in this study was 7, while in another study it was 7.9 (Liu et al. 2021) with the same staggered seat. However, in that study there were not always neighbors, which might indicate the importance of privacy. Torkashvand et al. (2019) showed that in a conventional configuration, the middle seat is the least preferred one, because of the contact to neighbors, however, passengers that travel in groups like to have seats next to each other and they do not bother about the shoulder contact. So, probably for groups this seat might not be ideal, but this issue needs to be further investigated.

Fig. 6. In the staggered seat there is no shoulder contact and there is a separate space at the armrest.

An important limitation of this study and the previous study on staggered seats (Liu et al. 2021) is that the participants tested the seat for only 10 min. Smulders et al. (2016), Li et al. (2017) and Vanacore et al. (2019) show that discomfort increases over time. Therefore, long term tests are needed in order to confirm whether the observed effects hold for a 6–12 h flight.

5 Conclusion

A staggered seat was tested for a new aircraft configuration where passengers are positioned in the wing. The longitudinal axis of the cabin inside the wing has an angle of 26° with respect to the flight direction. The seats were placed in the direction of flight,

which means that they had an angle towards the cabin and the adjacent seat closer to the middle of the airplane is slightly shifted backwards. This staggered position has the advantage that shoulders do not touch each other and arms have a separate spot at the arm rest. This study showed that the participants experiencing both this staggered seats and regular seats rated comfort for specific seat features and privacy of the staggered seats higher.

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References

Agresti, A.: Analysis of Ordinal Categorical Data, vol. 656. Wiley, Hoboken (2010)

Ahmadpour, N., Robert, J.M., Lindgaard, G.: Aircraft passenger comfort experience: underlying factors and differentiation from discomfort. Appl. Ergon. **52**, 301–8 (2016)

Anjani, S., Li, W., Ruiter, I.A., Vink, P.: The effect of aircraft seat pitch on comfort. Appl. Ergon. **88**, 103132 (2020)

McCullagh, P.: Regression models for ordinal data (with discussion). J. R. Stat. Soc. Ser. B **42**, 109–142 (1980)

Humm, J.R., Yoganandan, N., Pintar, F.A., Weese, R.L., Moorcroft, D.M., Taylor, A.M., Peterson, B.: Responses and injuries to PMHS in side-facing and oblique seats in horizontal longitudinal sled tests per FAA emergency landing conditions. Stapp Car Crash J. **60**, 135–63 (2016)

Liu, Z., Rotte, T., Anjani, S., Vink, P.: Seat pitch and comfort of a staggered seat configuration. Work (Preprint) 1–9 (2021)

Smulders, M., Berghman, K., Koenraads, M., Kane, J.A., Krishna, K., Carter, T.K., Schultheis, U.: Comfort and pressure distribution in a human contour shaped aircraft seat (developed with 3D scans of the human body). Work **54**(4), 925–940 (2016)

Torkashvand, G., Stephane, L., Vink, P.: Aircraft interior design and satisfaction for different activities: a new approach toward understanding passenger experience. Int. J. Aviat. Aeronaut. Aerosp. **6**(2), 1–14 (2019)

Vanacore, A., Lanzotti, A., Percuoco, C., Capasso, A., Vitolo, B.: Design and analysis of comparative experiments to assess the (dis-) comfort of aircraft seating. Appl. Ergon. **76**, 155–63 (2019)

Vink, P., Rotte, T., Anjani, S., Percuoco, C., Vos, R.: Towards a hybrid comfortable passenger cabin interior for the flying V aircraft. Int. J. Aviat. Aeronaut. Aerosp. **7**(1), 1 (2020)

Li, W., Yu, S., Yang, H., Pei, H., Zhao, C.: Effects of long-duration sitting with limited space on discomfort, body flexibility, and surface pressure. Int. J. Ind. Ergon. **58**, 12–24 (2017)