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Emergency evacuation from double-deck aircraft [1]

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ABSTRACT: Airbus Industrie is considering building a family of double-deck aircraft. A research project was initiated primarily to investigate the effects of the height of the new upper deck on human performance in case of an emergency, but it was also investigated whether factors such as visibility, slide design, and passenger safety instruction might influence individuals‘ performance. A performance model was developed that includes (a) situational / technical and individual dispositional factors, (b) cognitive and emotional reactions to the situation, and (c) performance features. Based on this model, new tools were developed for assessing dispositions and reactions, for analyzing behaviors at the exit, in the slide, and on ground, and for measuring times for the evacuation steps. These tools were applied in partial tests that were carried out on a double-deck mock-up with one exit.

Airbus Industrie is considering building a family of double-deck aircraft with a capacity of 550-850 passengers. This aircraft will have a full-length upper deck with a twin-aisle cabin. The height of the upper deck is connected to a number of new issues. One such issue is the process of evacuation in case of an emergency. After all, the height of the door sill on the upper deck will be around 8 m, or possibly up to 11,5 m, for instance in the event of a broken gear when the body of the aircraft is in a slanted position. Hesitation of passengers at the exit could impair the performance of evacuees. A research project was initiated by *DaimlerChrysler Aerospace Airbus* in Hamburg to study the psychological effects of the new upper deck situation on human performance. The major task consists of investigating the effects of the height of the upper deck, but we will also investigate whether other factors, such as visibility, slide design, and passenger safety instruction might influence performance in these circumstances as well.

Model

At the outset of the study, a model was developed to guide the empirical tests (Figure 1: A general psychological model of aircraft evacuation performance). This model includes the following components: *First*, the situational and individual dispositional factors that are assumed to determine egress performance. *Situational factors* are configurational factors (e.g., exit design), environmental factors (e.g., visibility), procedural factors (e.g., flight attendant´s instructions), and social factors (e.g., others passengers´ behavior*). Individual dispositional factors* are height-related physical attributes (e.g., age) and height-related mental dispositions (e.g., fear of height). *Secondly*, the cognitive, emotional, and physiological reactions to the situation that are assumed to determine performance. *Thirdly*, the performance features that are important for evacuation time and outcome.

Research Questions and Tools

The effect of four situational factors was investigated: height of deck (5,3 m vs. 8 m), design of slide (canted vs. curved), visibility (day vs. night), and safety instruction (with vs. without a video). In this presentation, the focus will be on the development of the research tools and on data from the pilot tests on two factors, deck height and slide design: First, what is the effect of the height of the new upper deck on performance, compared to the influence of the height of the main deck? This question is naturally very interesting because the new aircraft has two decks. Second, what is the effect of the design of the slide on human performance? This question is interesting because two types of slides have been developed of which one is more curved and has higher sidewalls than the other.

With respect to the effect of individual dispositions, the question was whether specific physical or mental dispositions might have different effects on human performance from the upper deck than from the main deck. For the assessment of height-related dispositions, two questionnaires were developed. The *H*eight-Related *P*hysical *D*isposition *Q*uestionnaire (HPDQ) assesses physical features such as gender and age. The *H*eight-Related *M*ental *D*isposition *Q*uestionnaire (HMDQ) assesses individuals´ tendency to show acrophobia, aviaphobia, claustrophobia, fear of loss of control, and vertigo, as well as their risk attitude.

With respect to the dependent variables, the project focussed on emotional reactions (e.g., feeling of anxiety) and cognitive reactions (e.g., risk perception), and on human perfor-

mance. These reactions were assessed with the *H*eight-Related *R*eaction *Q*uestionnaire (HRQ), consisting of questions constructed specifically for the project. Many items were taken from the State-Trate-Anxiety-Inventory (Spielberger, 1972), adjusted to the present purpose, but a number of items were newly developed. An example of an item about the level of anxiety, asked shortly before the test: „I am worried that something might go wrong“. An example of a question concerning risk perception, asked shortly after the test: „I was worried I might fall off the slide“.

In development tests like the ones that will be run in the current project it is important to analyze the behavior in a more comprehensive way, including in particular relevant features of human performance. For instance, whether participants hesitate at some point during the evacuation process, where they look at the exit, and how they jump and slide. Human performance was recorded through five video cameras positioned inside and outside the test stand. For the main tests, a new time measurement system will also be installed in order to assess exact time measures for the phases of the evacuation process.

Procedure

Pilot tests were carried out on the so-called Megaliner, a double-deck mock-up with 42 seats and with one exit. In each of these tests, volunteer subjects were seated in the cabin and, after a call-to-evacuate, were asked to leave the cabin by jumping into the erected evacuation slides.

In condition A, the test was performed from the upper deck (8 m) with the curved slide, in condition B, from the upper deck with the canted slide. In condition C, the test was performed from the main deck (5,3 m); this condition served as control. (Furthermore, all tests were also run under high vs. low visibility and with and without a specific safety instruction but these conditions will not be discussed in the present paper).

Each test run consisted of five stages: In *stage 1*, subjects arrived and filled out the questionnaire regarding physical and mental dispositions (HPDQ and HMDQ). In *stage 2*, they were taken to the hall where the Megaliner was set up, were led up onto the main resp. upper deck, took their seats, were briefed by a flight attendant, and filled out the questionnaire regarding emotional and cognitive reactions (HRQ-pre). In *stage 3*, the evac

signal was given, subjects were led to the exit door and jumped onto the slide. In *stage 4*, subjects immediately went to a room where they again filled out the questionnaire concerning emotional and cognitive reactions (HRQ-post).

Subjects were recruited among the company´s work force. The age / gender distribution matched roughly the JAR 25.803 requirement; only the proportion of women over 50 years of age was lower than required.

Results

In this paper, only data from the pilot tests will be reported. Pilot tests were needed in order to establish the functioning of the technical and experimental setting and the reliability and validity of the psychological measurements. Therefore, these data can serve only an illustrative purpose and do not allow conclusions with respect to human performance and evacuation outcome with actual new aircraft.

The effect of deck height

(1) Reactions (HRQ)

An analysis of variance was performed on the HRQ-pre data (stage 2) to see if subjects on the upper deck reacted to the situation in a different manner than subjects on the main deck, or, to be more precise, whether subjects of the upper deck groups had a higher level of anxiety immediately before jumping than subjects of the main deck group. No significant difference was revealed. It is not surprising that the reactions of the participants in the two conditions, upper deck and main deck, did not differ. After all, they had not seen the height of the exit from which they were to jump. A significant difference in level of anxiety would have indicated that subjects, while they were still sitting in the cabin, had started to imagine the heights of their decks exit.

The HRQ-post scores (stage 4) did not differ significantly from the HRQ-pre scores (stage 2). An analysis of variance was performed on the HRQ-post data to see if subjects who had jumped from the upper deck reacted in a different manner than subjects who had jumped from the main deck. The scores of the latter group are significantly higher than those of the former. It is remarkable that the reactions in the two conditions are different because one would have have expected the same level of (reduced) height-related anxiety in both

groups, in particular because the groups had shown no different reactions in the cabin. Even more remarkable is that the main deck group shows a *higher* height-related anxiety *after* the jump than before the jump. The upper deck groups, on the other hand, show the expected *reduced* height-related anxiety.

(2) Performance

The video footage was analyzed by two observers. Performance of test participants at the exit was scored according to a set of seven categories of behaviors (e.g., subject looks around, sits down, hesitates). 8,1% of participants showed such critical behaviors at the exit. The largest category (6,8%) included hesitating behaviors. The frequency of critical behaviors is higher on the upper deck (9,5%) than on the main deck (5,%), but this difference is statistically not significant.

The Exit Hesitation Time (EHT) of a subject S_n is defined as the time between the moment when S_n hits the slide and the moment when the subject jumping ahead of S_n, subject S_{n-1}, has hit the slide. The average EHT of the upper deck groups was 1,53 seconds, the EHT of the main deck groups was 1,19 seconds. This difference is statistically significant.

The effect of individual dispositions

(1) Reactions (HRQ)

A general tendency to show anxiety (in situations sharing features with an evacuation situation) should dispose subjects to show higher anxiety in the test situation. In other words, we would expect a correlation between the HMDQ scores of subjects and their HRQ scores. The data support this expectation. The correlation of the HMDQ scores with the HRQ-pre scores is 0,50 ($p<.01$), and the correlation with the HRQ-post scores is 0,28 ($p<.01$). The decrease is not surprising because the situation after the jump is clearly more relaxed than the situation before the jump. The relatively high correlation implies that the emotional reaction of a person to the evacuation situation can be predicted with a certain probability.

(2) Human Performance

Subjects who showed critical behaviors during the test were compared with subjects who did not show such behaviors. The major difference was a physical attribute gender:

Whereas only one third of test participants were women, two third of the subjects showing critical behaviors were women. With respect to the mental attributes, subjects who showed critical behaviors also had slightly (but not significantly) higher scores on the HMDQ subscales *fear of height* and *vertigo*. At the same time, however, these subjects seem to be less worried to loose control and to be prone to take risks.

No significant correlation was observed between the HMDQ scores and the Exit Hesitation Time (EHT). Hesitation times can not be predicted from subjects general tendencies to show anxiety in height-related situations.

We further looked at the correlation between the HPDQ score and the EHT. The correlation of 0,34 is highly significant ($p<.01$): Subjects who reported physical attributes hesitated longer than subjects who did not report such attributes. Of particular interest is that the correlation is 0,38 for subjects from the upper deck groups ($p<.01$) but only 0,18 for subjects of the main deck group (n.s.). The physical attributes seemed to have a greater effect on human performance on the upper deck than on performance on the main deck.

An analysis of variance was performed on the EHT with age and gender as factors. There are significant main effects of both factors as well as a significant interaction: Women over 50 years of age have a significantly higher EHT, a result reported previously also in other studies (e.g., Johnson & Altman, 1973).

Summary

The findings from the pilot tests reported in this paper can be summarized as follows:

(1) Exit Hesitation Time was higher on the upper deck than on the main deck, suggesting an effect of the height of the deck.

(2) The physical attributes seemed to have a greater effect on performance on the upper deck than on performance on the main deck.

(3) Women over 50 years of age had a significantly higher EHT on both decks.

(4) Subjects who had a general tendency to show anxiety (in situations sharing features with an evacuation situation) were disposed to show anxiety in the test situation.

(5) Only a small percentage of test participants showed critical behaviors at the exit. The majority of these subjects were women.

In conclusion, the technical and organizational design of the evacuation from a second deck as high as proposed for the new aircraft suggests additional research efforts. Although performance of test participants was not very different under the two conditions (upper deck and main deck), there were some differences in the hesitation time that need to be examined more closely.

The pilot tests were important to examine and demonstrate the value of the technical and psychological setting and tools, in particular the questionnaires, the schema for the analysis of subjects´ behaviors, and the time measurement system. These tools were constructed and developed in the current project largely from scratch due to the novelty of the aircraft, they have been revised and improved following the pilot tests, and they provide now better possibilities for research on aircraft evacuation than existed before.

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Footnotes

FN 1: The research reported in this paper is part of a project performed under contract with DaimlerChrysler Aerospace Airbus GmbH, Hamburg. All conclusions and opinions expressed in this paper are those of the authors.

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