Paper presented at the 5th Australian Aviation Psychology Symposium, November 20-24, 2000, Manly/Sydney

A psychological model of emergency evacuation from double-deck aircraft

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Two aircraft companies are in the process of planning what sometimes is called the Very Large Transport Aeroplanes (VLTA). Airbus Industrie has decided to build such an aircraft, Boeing is considering extending the present upper deck of their jumbo aircraft. That is, in the near future, we will see a new type of aircraft, a double-deck aircraft. The height of the upper deck is connected to a number of safety-related issues. One such issue concerns the evacuation of passengers in case of an emergency. For instance, passengers on the upper deck might hesitate to jump into the slide, or jump in an awkard posture, or even refuse to jump at all. In this event, this could lead to the evacuation process taking longer than the 90 seconds laid down by the regulations - a time limit that may have to be demonstrated in a full-scale evacuation exercise prior to aircraft certification. Ultimately, this could mean that limits on passenger capacity might have to be set in order to ensure that the evacuation of all passengers is achieved within the given period of time and with the required safety.

A thorough investigation of these issues has to combine empirical testing and theoretical analysis. On the empirical side, tests have to be run with groups of subjects under different conditions. In order to minimize possible injuries, however, such tests would have to use only partially representative samples of subjects. Tests could not be run under typical emergency conditions, in particular not under high time pressure. On the theoretical side, present knowledge from previous emergency evacuation studies as well as from related studies in psychology, ergonomics, and engineering can be used to design the appropriate tests and to interpret and generalize potential test results.

Based on a review of past research and reports, we propose a psychological model of performance that focuses on the cognitive, emotional, and physiological reactions of individual passengers and the resulting egress behavior when passengers have to evacuate from a VLTA. This model is shown in Figure 1. It is important to note that the model does not include *all* factors which have or might have an effect on evacuation performance per se, such as seat arrangement, exit width, or flight attendant behavior. We consider primarily those factors which might make a difference for evacuation behavior from an upper-deck aircraft compared to the evacuation behavior observed on conventional aircraft. Furthermore, we look at the effects of these factors on the performance of passengers when they have to evacuate using slides, rather than stairs or platforms. In these respects, the model goes beyond previous conceptions of and research on emergency evacuation, a step necessitated by the new aircraft design.

Empirical research has to address the question whether and how *double-deck aircraft-specific factors*, in particular the height of the deck, may influence the reactions of individual passengers and their performance in the cabin, at the exit and on the ground. New methods and techniques for measuring reactions and their effects on performance have been developed and will be applied. In this paper, only the general psychological model will be described. A more specific model that has guided tests of evacuation behavior under different conditions is presented in Jungermann and Goehlert (2000).

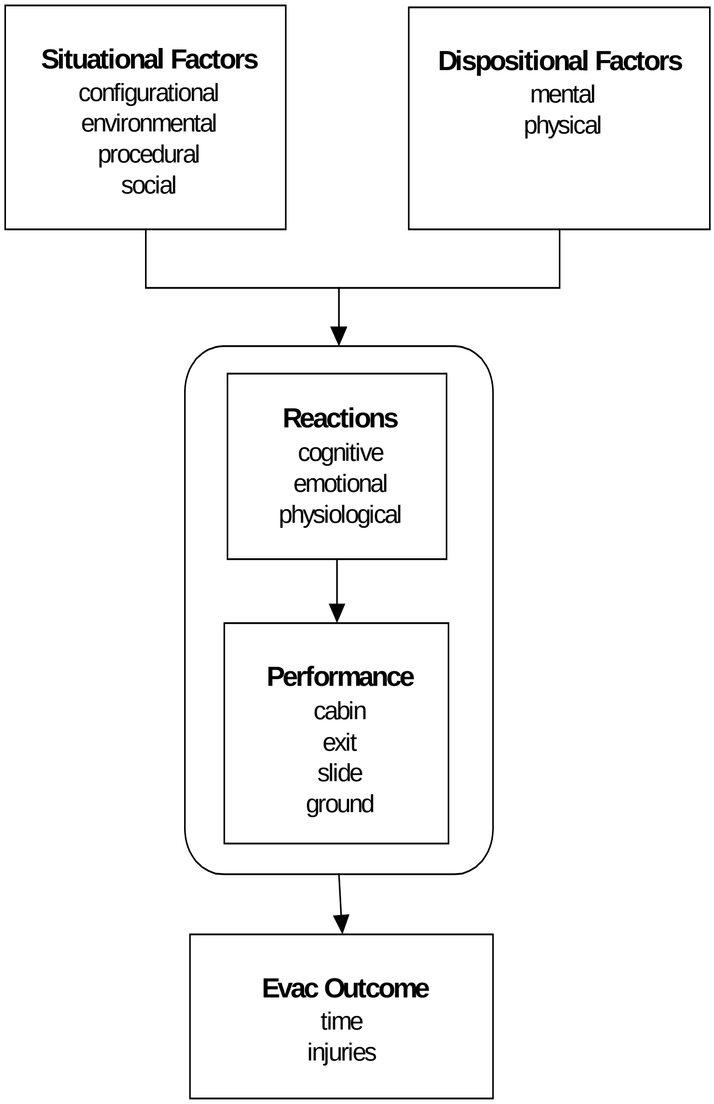

Figure 1: A general psychological model of aircraft evacuation performance

Situational and dispositional factors

On the upper deck, passengers' reactions at the exit are assumed to be determined by *situational* as well as by *dispositional* factors.

Situational factors

Usually, four kinds of situational factors are distinguished: configurational, environmental, procedural, and behavioral factors. In the past, a number of configurational, environmental, procedural, and behavioral factors have been examined with respect to their effects on the evacuation outcome. These factors are all located *inside* the cabin and have all been studied with conventional aircraft only. No study seems to have been undertaken regarding conditions and events that take place *outside* the cabin, ie., at the open exit, on the slides, on the ground, and on how passengers perform when they arrive at the open exit door. Such factors also have to be considered when studying evacuation from an upper deck.

1. Configurational factors. Traditionally, configurational factors include the number of seats and the seating arrangement, the number of aisles, the number, location and type of exits, exit width and other factors. Numerous studies have analyzed how evacuation outcomes are related to these factors. Galea, Owen and Lawrence (1996) and Muir (1996) review some of these studies. But which new factors might be important in the given context? Our model includes the following: deck height, slide steepness, type of slide, exit width and design, number of people on the slide.

I will not elaborate on all factors but only comment on deck height which is the the factor of most obvious significance. The effect of the height of the upper deck may be important because it is well-established that humans (as well as animals) show fear and avoidance of heights (Gibson, 1969; Menzies & Clarke, 1995a). Fear of height is natural and justified, as long as it does not become phobic, ie., excessive and disproportionate to the situation. The increased height of the upper deck, as compared to the height of the lower deck, can thus be expected to affect all passenger, possibly resulting in increased hesitation time.

2. Environmental factors. Environmental factors considered in previous research include exposure to fire, heat, toxic and irritant gases, and smoke inside the cabin. We assume that outside the cabin, important factors affecting an evacuation from the upper deck may be water, smoke, and reduced visibility due to darkness or fog.

We assume in particular that restricted visibility will increase the passengers´ feelings of threat and insecurity. This is the general psychological effect of darkness. Therefore, restricted visibility of the aircraft's environment and in particular of the slide and the situation on ground might increase the passengers´ hesitation time at the exit. However, one might observe the opposite effect: passengers might feel safer under the condition of low visibility compared to high visibility because they cannot see how high the exit door actually is, and they might jump readily into the slide because they cannot see down to the ground, where there may be (possibly injured) passengers jammed at the bottom of the slide.

3. Procedural factors. Procedural factors include the actions of staff, including their verbal and written instructions. The importance of crew procedures on double-deck aircraft has been emphasized repeatedly (eg., JAA conference, 1998; Muir, 1996). In the new aircraft, the following factors have to be considered: pre-evacuation instructions, flight attendant´s verbal actions, and flight attendant´s physical actions.

For an evacuation from the upper deck, flight attendants might have to use different verbal instructions and commands when passengers arrive at the exit door. For instance, if passengers hesitate or refuse to jump into the slide, flight attendants might have to appease, to encourage, or to order them to jump in their own best interest and also in the interest of their fellow passengers still in the cabin. And present pre-evacuation instructions might have to be changed if they are to result in passengers jumping correctly into the slide from the upper deck.

4. Social factors. Social factors include passengers´ initial response to the call to evacuate, panic flight reactions, behavioral inaction, group interactions, competitiveness, and some others. We consider the following factors as specifically important for double-deck aircraft: behavior of fellow passenger´s in the cabin, egress behavior of fellow passengers, number of passengers, and general behavior of fellow passengers.

Are passengers likely to behave differently on a double-deck aircraft, and could this be of consequence in the case of an evacuation? Possibly, at least on the upper deck. The height of the deck might lead passengers, for instance, to let other passengers go first, to wait and see how they behave at the exit. Passengers might also feel so relieved when they arrive on the ground that they not leave the slide fast enough or walk away far enough.

Dispositional factors

These are the double-deck aircraft-specific *mental and physical dispositions* of passengers, ie., dispositions which may have a different effect on the upper deck than on the lower deck.

1. Mental dispositions. People differ in a number of personality features which might affect their behavior in case of an emergency evacuation. For instance competetiveness, altruism, and feelings of responsibility. With respect to the new aircraft, two features might have a specific effect on evacuation behavior: trait anxiety (fear of height, fear of flying) and attitude towards risk.

The height of the upper deck might pose a problem for those passengers who suffer from acrophobia (fear of height) or aviaphobia (fear of flying), or for passengers who freeze or panic on high buildings. Since airlines report that about 30% to 40% of all passengers suffer to some degree from a fear of flying, it might be that aviaphobia and / or acrophobia become crucial factors in a double-deck aircraft if they induce freezing or panic behavior by a significant number of passengers on the upper deck (see also van Gerwen, Spinhoven, Diekstra and Van Dyck, 1997). Since research has shown that people suffering from acrophobia seem to be in a particular state of anxiety *before* an anticipated event, but once the event actually takes place, they deal with it as well as any other person (Andrew, Freed & Teesson, 1994), attention would have to be placed on the period of anticipation of the event (ie., standing at the exit and looking down).

Passenger performance at a certain height of the upper deck might also be related to the willingness of passengers to take a risk, or, in the present context, to the *aversion* of certain passengers to take a risk task (Yates, 1992; Jungermann & Slovic, 1993). Jumping from the upper deck into a slide is similar to activities such as bungee jumping, except that in an emergency evacuation the action has to be performed involuntarily. The question is, therefore, whether those people who are clearly risk-averse in the sense that they would never voluntarily jump from a high object may have a particular problem with an evacuation from the upper deck.

2. Physical dispositions. Naturally, a number of physical dispositions of passengers must be considered, in particular: age, weight, gender, pregnancy, agility, height vertigo, and tiredness.

However, although most of them can be assumed to affect the number and severeness of injuries, it seems unlikely that they will have a different effect on passengers' reactions and behaviors on the upper deck than on the lower deck.

Reactions and performance

The core of the model are passengers' cognitive, emotional, and physiological reactions as far as they might be different on the upper deck than on a lower deck. Furthermore, only such reactions are considered that can be assumed to have an effect on passengers' actual evacuation performance.

Reactions

1. Cognitive reactions. Previous research has largely ignored cognitive reactions and has focused on emotional reactions. However, cognitive reactions like passengers' perception or imagination of the exit, the slide, and crew behavior might have a considerable influence on their emotions and their behavior, in particular in the pre-evacuation stage. The model emphasizes four kinds of reactions: judgment of risk and danger, reduced or enlarged perceptual field, selective attention to other people´s behavior, and loss of control.

The perceived risk and danger may be measured with questionnaires. The perceptual field requires a different approach. We have developed a picture-matching technique which requires a subject immediately after a test evacuation to take a look at three pictures showing the view from the exit door with different zoom factors, and to pick the one which best matched the perspective that the subject had had at the exit door. The question is whether subjects' attention is captured by the slide to such a degree that their perspective is a kind of tunnel view, or whether they are able to pay attention to the surroundings and, in particular, can notice the height.

2. Emotional reactions. These reactions to the situation are at the center of interest because the obvious assumption is that the situation on the upper deck might cause a number of passengers to react with intensified emotions that could affect their performance. One reason could well be that they have never in their lives performed a jump as requested (ie., without sitting down) from such height. The model includes emotional agitation, feelings of anxiety, feelings of safety, and feelings of helplessness.

Emotional reactions are usually assessed with questionnaires. For the present purpose, we have developed questionnaires to assess the feelings of anxiety and safety subjects feel in the cabin immediately before the call to evacuate, and to assess subjects' feelings immediately after an evacuation.

3. Physiological reactions. As before, such reactions are of interest only in as far as they may be assumed to be different on the upper deck than on a lower deck. Measurement of physiological reactions would be rather difficult in evacuation tests, however, and they may not play a major role in any empirical research. Heart rate, blood pressure, body temperature, and nausea would be candidates for measurement.

Performance

Many performance features may be related to the outcome. We distinguish how passengers behave *in the cabin*, *at the exit*, *on the slide*, and *on the ground*. These behaviors can all be observed with video cameras.

1. Performance in the cabin. Examples of possibly relevant features are whether people hesitate to get up from the seat, let other passengers pass by in the aisle, or stop on the way to the exit and cause a jam.

2. Performance at the exit. Examples of possibly relevant features are whether people hesitate or even refuse to jump, freeze and block the open door, act overhastily and jump too fast, sit down, jump in the wrong manner, or close their eyes.

3. Performance on the slide. Examples of possibly relevant features are how passengers hold their arms, what they do with their hands and feet, whether they cross the lane divider or collide with others.

4. Performance on the ground. Examples of possibly relevant features are whether people stay in the slide or stand around the bottom of the slide.

Evacuation Outcome

Finally, the performance of the individual passenger contributes to the overall evacuation outcome. The variables of interest are the average *egress time* and numbers and type of *injuries*.

Testing the model

The model that I have outlined probably includes most of the factors which could possibly have an effect on individual passenger egress performance from the upper deck. An empirical study would have to focus only on a small number of factors.

First, several factors need not be examined because their specific effect on the evacuation from an upper deck can be predicted by extrapolating from findings reported from evacuations from the conventional main or lower deck. The higher the age of the evacuee, to take an example, the higher are egress time and number of injuries. For obvious reasons this statement will hold true for upper deck evacuations, too, and will therefore not necessitate any additional verification. The same goes for a number of factors whose effect will probably be increased when passengers are evacuated from the upper deck compared to when they are evacuated from the lower deck.

Second, certain factors cannot be studied empirically for ethical, practical, or financial reasons. The slide, for instance, cannot be tested in the extremely steep position which it may take up when the aircraft is in a slanted position due to a broken gear. Still more important is that it is impossible to study the effect of the situation on the ground on egress performance. If passengers stand in the exit door and see other passengers stacked up at the bottom of the slide (because they did not leave the slide or did not move fast enough away from the slide), they can be expected to hesitate until the situation has changed. Such behavior would be perfectly rational from the individual passenger´s point of view because sliding into other passengers from the height of the upper deck (as well as from the lower deck) poses high risks of severe injury. However, if the present procedures on the ground remain as they are, it is very likely that people will be stacked up at the end of the slide.

Therefore, empirical research should focus on those factors and variables that are of particular relevance: The *situational factors* should include deck height, visibility, and evacuation instructions; *dispositional factors* should include passenger anxiety and risk attitude. With respect to *cognitive and emotional reactions* the focus should be on those that are likely to influence egress performance and that can be measured, such as risk perception and level of anxiety. And with respect to *performance features* one should focus on those that have a high chance of influencing the egress time and the probability of injury, such as hesitation and body movements. More research based on such a specific psychological model should provide data important for aircraft developers as well as airlines.

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