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Effect of Passenger Behaviors and Psychological Characteristics on Emergency Evacuation

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Abstract

Passenger behaviors and psychological characteristics are vital factors that effect the emergency evacuation strongly. The emergency evacuation simulation demo tests and recall tests were carried out in this study. Combined with questionnaires survey, passenger typical behaviors and corresponding psychology are discussed. The results show that evacuation time, safety knowledge, passenger choosing rule for evacuation exit and route, passenger behaviors when facing congestion, and other typical behaviors and psychology are important factors that effect evacuation process. The results have sound perspective for improving emergency evacuation more efficient and making computer simulation on emergency evacuation process more accurately.

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1. Introduction

Emergency evacuation is the most important process after aircraft crash landing. The goal of emergency evacuation is to make the survived passengers evacuating from aircraft safely and quickly. According to the statistics of ICAO, approximately 90% passengers have survived by emergency evacuation in the aircraft accident worldwide during 1998 to 2007\cite{1}. The emergency evacuation is a vital measure to improve passengers’ survival rate.

In order to ensure passengers evacuating with satisfied efficiency in the aircraft accidents, some aircraft design factors, such as evacuation exit, escape route, aisle and etc., are required by FAA, EASA and

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CAAC. Emergency demonstration test is also required to show the airworthiness compliance, for which the evacuation must be completed within 90 seconds [2-4].

Besides the physical environment factors, passenger features also have great influence on emergency evacuation process. In those studies that considered passenger features, the issues were focused on human physiological characteristics, such as body size, age, gender and so on, but passenger behaviors and psychological characteristics were considered seldom because of the difficulty to understand them. Each passenger is an independent body with active and intelligent. His/her action and thought may various depending on the surrounding and his/her own background. For an individual person, the psychological characteristics such as whose risk judgment capacity, cultural background, education background, emergency information acquisition ability, emergency decision making ability, psychological enduring capacity and etc, have various degree impression on emergency evacuation behavior. Some researches have been done on passenger panic mentality and selfish behavior, which could cause escape channel congestion, emergency exit not fully rational use, evacuation time delay, and even result in emergency evacuation failure [5].

Because the main factors that influence the evacuation, including physical environment, information transmission mode, emergency system composition and passenger features, would impact the evacuation process through passenger psychological reaction and ultimately show as passenger behavior. So passenger behavior and psychology should be considered as significant factors that effect the evacuation strongly, and should be an important new research content for evacuation improving.

This study simulated the passenger compartment interior layout of a single channel aircraft. The emergency evacuation simulation tests were carried out according to CCAR25 Appendix J, which describes the requirements of emergency evacuation demonstration, and other relative airworthiness regulation clause. By the analysis of the subjects’ performance in the evacuation tests, combined with psychological questionnaires, passengers’ behaviors and psychological characteristics will be discussed in this study.

2. Implementation of emergency evacuation simulation tests and questionnaires survey

In order to discover the impact of passenger behaviors and psychological characteristics on emergency evacuation, simulation demonstration tests and questionnaires survey were carried out. The ARJ21B, which belongs to ARJ21 series business type, was used as the prototype here. The passenger compartment layout is shown as Fig.1. There are totally 22 seats in the passenger compartment, including two seats for flight attendants. The passenger compartment width is 123.7 inches, seats row distance is 38 inches, and aisle width is 19 inches. There are 2 doors and 2 emergency exits. The emergency exits are type II, which are set here as rectangular opening 20 inches wide by 44 inches high, with corner radii of 7 inches.

![Fig.1 ARJ21B passenger compartment layout](image)
Referring to the requirements of CCAR25.803 to 25.815, and Appendix J, designed the passenger compartment physical environment, passengers compose, and evacuation procedures. Then the emergency evacuation simulation demo tests were carried out, for two times. 33 people participated in the tests voluntarily, some of them involved in twice. According to the airworthiness regulation, the number of opened door or emergency exit should be less than 50% in the emergency evacuation demo. So in this study only one door or one emergency exit was opened in each test. For the first test, No.1 door was available, the second test, No.2 emergency exit was available.

The evacuation processes were recorded by camera. After demo tests, each participant was asked to do a recall test. In this test, each participant should recall his/her own evacuation process, then marked which door or emergency exit he/she escaped out, drew down his/her evacuation route, and marked the congestion place on the passenger compartment layout showed as fig.1.

In order to understand better on passenger behaviors and psychological characteristics during emergency evacuation, the questionnaires survey was conducted, for which 100 copies were provided, 91 were took back, 86 were effective. The questionnaires included three dimensions:

♦ Personal information

Personal information included passengers’ age, gender, education level, flight frequency, and so on. Among the investigated passengers, there were 45 males and 41 females, accounted for 52% and 48% respectively. For the distribution of their age, 5% accounted for younger than 18 years old, 35% for 18 to 35 years old, 38% for 35 to 50 years old, 20% for 50 to 70 years old, 2% for older than 70. For flight frequency, 48% of them by air often (at least 3 times a year), 38% occasionally (once in recent three years or more long time), 14% never by air before.

♦ Passengers’ concerning on emergency evacuation safety knowledge

Investigating on how much the passengers know about emergency evacuation safety knowledge, including whether know the exit location, whether read safety instruction, whether watching safety demonstration and so on.

♦ Passengers’ behaviors and psychological principles

Investigating on passengers’ behaviors and psychological principles when they face the emergency evacuation, including the choose rule for evacuation exit and route, the action and feeling in front of congestion, and so on.

Comprehensive analysis on simulation demo tests, recall tests and questionnaires survey would be helpful to understand passenger behaviors and psychological characteristics all-sided in the emergency evacuation process.

3. Analysis on results of simulation demo tests, recall tests and questionnaires survey

3.1. Evacuation time

The information from emergency evacuation simulation demo tests was shown in table 1. It could be seen that the total evacuation time of second demo test was far less than the first demo test. This was mainly because of, compared with the first demo test, less evacuation time that the first successful escaped passenger using, less reaction time for the slowest passenger, and less congestion situation in the second demo test.

Table 1  Information from emergency evacuation simulation demo tests
The reaction time of passengers had a great influence on the total evacuation time at the beginning of emergency evacuation. It had relationship with the time of the first few passengers arrived at the exit. The following passengers were mostly in the line waiting for passing the exit, so less time the first few passengers arrived at the exit, less time the total evacuation process using. Obviously, the seat position and moving speed were also important factors for the first few passengers to arrive at the exit. After any passenger arrived at the exit, the speed that passenger passing the exit became the top factor to influence total evacuation time. More passengers queued at the exit, more heavily the passing exit speed affect the total evacuation time. Meanwhile the other factors, such as passenger moving speed in the cabin, went out relatively as secondary factors. Table 1 indicated that the maximum number of passengers queued at the exit was 16 people in the first demo test, which was more than that in the second demo test. The video also implied that passengers passed the exit slower in the first demo test than that in the second one. So during the latter evacuation process, the speed that passenger passing the exit, or the exit capacity, influenced the total evacuation time extremely.

3.2. Passenger understanding of emergency evacuation safety knowledge

Before the simulation demo tests began, the safety instruction had been put on each passenger seat, and safety demonstration was shown in front of all passengers. Both of the safety instruction and the safety demonstration declared the location of doors and emergency exits. But the recall tests found that some passengers still didn’t know the location of doors and emergency exits, and even more, some of them couldn’t tell which exit they escaped from. The recall tests statistics indicated that 2 passengers marked the exit location wrong according to their first demo test memory, and 5 passengers marked the exit location wrong according to their second demo test memory. 2 passengers were unable to mark the exit location because they said they didn’t remember the exit location and the evacuation process at all. For these passengers who marked wrong exit location and couldn’t remember the exit location, their seats were far away from doors and emergency exits. The video showed that most of them were not initiative to choose exit to escape, but were in confusion and in the status of herd behavior. This was exactly why they couldn’t recall the exit location and the evacuation process clearly.

The questionnaires survey indicated the similar results. Fig.2 showed that a high percentage of people didn’t know the location of emergency exit, no matter which age group they belonged to. Comparing fig.3 and fig.4, it could be seen that more people would watch/listen the safety demonstration illustrated by flight attendants, rather than read safety instruction manual. While it’s not a good phenomenon that so high percentage of people didn’t read safety instruction manual, or didn’t watch/listen the safety demonstration, whether they by air often or frequency. More frequency the passengers traveled by air, more likely that they won’t to concern the emergency evacuation safety knowledge.
Fig. 2 Passenger understanding of emergency exits location

Fig. 3 Whether read safety instruction manual
3.3. Passenger choosing rule for the evacuation exit and route

The simulation demo tests and recall tests indicated that passenger was inclined to choose the closest exit or the directly visible exit, with their first reaction, when the emergency evacuation started. This was coincident with the research of Prof. Galea, who carried out a BWB emergency evacuation simulation demo test. He found that passenger always left from the seat nearest exit[6].

While our tests found some exceptions. If passengers seated in the middle of passenger compartment, far from the doors and emergency exits, such as passengers seated at No.13 and No.14 seats (see fig.1), they showed hesitating in choosing exit. They went back and forth, and ultimately became following person, or called herd. Most of them chose to follow the direction of the masses at last.

The questionnaires survey revealed the similar results, shown as fig.5. It indicated that the majority of passengers would like to choose the nearest exit from them selves. Other passengers prefer to follow the masses or circumvent the crowd. Passengers choosing to follow were slightly more than those who choosing to circumvent, in the case of they weren’t familiar with the surroundings.

![Diagram showing passenger choosing for evacuation exit and route]

3.4. Passenger behaviors when facing congestion

When the emergency evacuation began, most passengers took it for granted that all exits, including cabin doors and emergency exits, were available. The tests video and recall tests results showed that more than half of the passengers went to the nearest exit at the first time. When they found this exit was not available, they would immediately try to evacuate from the symmetry exit or near exit, rather than waiting at the end of the congestion crowd. Until they found the available exit and saw people evacuated successfully, then they lined up to follow the crowd forward. The tests video and recall tests results showed that 14 people appeared round behavior in the first demo test, 12 people appeared round behavior in the second demo test. This reflected clearly that vast majority of passengers were unwilling to stay and wait easily at the end of congestion crowd.

Passengers’ intolerance of congestion was also confirmed by the questionnaires survey, seeing fig.6. When facing a congestion exit, whether they knew the exit was available or not, more than 70%
passengers prefer to choose another exit and another evacuation route if they knew another exit was available. Even unsure whether any other exit was available, still 14% passengers (knew the congestion exit was available) and 21% passengers (didn’t know whether the congestion exit was available) prefer to choose another exit and another evacuation route. Only 10% passengers were willing to continue to wait in any case.

![Chart showing passenger behavior](image)

**fig.6** Passenger behaviors when facing congestion

### 3.5. Passenger panic emotion

Passenger panic emotion and action in different situations were investigated in this study. The statistics result was shown as **fig.7**.

![Chart showing passenger panic emotion](image)

**fig.7** Passenger panic emotion and action in different situations
In the case of flight attendant giving evacuation directive, 98% passengers would submit to flight attendant, follow the masses, and not find other exit by oneself. In this case only 2% passengers would be panic. In the case of nobody giving evacuation directive, the percentage of panic passengers increased to 7%, and approximately half of passengers (45%) would find other exit. In the case of failed to evacuate for a long time, the percentage of panic passengers climbed to 20%. Thus it could be seen that the methodical directing of flight attendant was a key factor in effective evacuation procedure. The flight attendant actually played a role of leader in the emergency evacuation process.

The survey statistics also shown that female was more likely to be panic than male. In a panic crowd, the proportion of females and males was 63% to 37%.

4. Typical behaviors and psychological characteristics in emergency

Many patterns of human behaviors and psychological characteristics in emergency have been discovered, such as leadership, fear, panic, impulsion, fluke, calmness, anger, cluster, herd, exclusion, along the wall, phototropism, retreat, back and forth behavior, inertial behavior and so on[7]. In this study, according to the information came from the emergency evacuation simulation demo tests, recall tests and questionnaires survey, three typical patterns of passenger behaviors and corresponding psychological characteristics influenced the evacuation process mostly. The three typical behavior patterns were leader behavior, herd behavior and panic behavior. Each of them had corresponding psychological characteristics support.

♦ Leader behavior

In an emergency evacuation of civil aircraft, the leader role is usually played by flight attendant. Compared with passenger, flight attendant is familiar with the emergency items, such as the location of emergency equipments, method of application, attention matters, the location of exits, the division of evacuation routes, etc. Also the flight attendant is trained to be skilled with the emergency evacuation procedures, and keep good psychological quality when emergency situation occur. These make the flight attendant become the best leader in emergency evacuation, whose methodical directing is a key factor in effective evacuation.

♦ herd behavior

In the process of emergency evacuation, due to the lack of one’s own logic judgment, the individual accepts unconsciously and follows other’s action, which is herd behavior. Herd behavior is a typical blind behavior. People choose to follow the direction of the big group to evacuate. Herd behavior always brings huge harm to evacuation. Passengers often stampede out on account of the survival instinct, which easily lead to exit congestion and evacuation time delay. Therefore, herd behavior must be guided effectively to ensure the emergency evacuation successful.

♦ Panic behavior

Panic is aroused by emergency and disaster that difficult to resist. It is accompanying with long-lasting psychological fear, nervous emotion, and ultra abnormal behavior. Panic person may lose his rational judgment ability, avoid the objective information and become “brain blank”. In the process of emergency evacuation, panic behavior could cause confusion, even result in crowded injury and crushed to death. Also, panic is gradually intensified and may infect other people with the accident lasting. So the person with panic and his panic behavior should be concerned seriously when emergency happen.

In fact, emergency evacuation of civil aircraft is a process with group interaction and influence. In this process, the phenomenon of the above three individual behaviors and psychological characteristics may turn into a group behavior and psychology. In emergency situation, these behaviors and psychologies are easy to interact and transmit. One obvious example, Herd behavior and corresponding psychology largely depend on the number and behavior of leader and panic person.
5. Conclusions

The emergency evacuation simulation demo tests, recall tests and questionnaires survey were implemented in this study. It was found that passenger’s reaction time, moving speed and passing exit speed affect the total evacuation time extremely. Passenger understanding of safety knowledge, passenger choosing rule for evacuation exit and evacuation route, passenger behaviors when facing congestion, passenger herd behavior, passenger panic emotion, and flight attendant leader behavior are all factors that should be considered in the purpose of improving evacuation efficiency.

The researches on passenger behaviors and psychological characteristics have sound perspective for improving emergency evacuation more efficient and making computer simulation on emergency evacuation process more accurately. For instance, according to the results of this paper, pay more attention to those passengers who concern less about safety knowledge, strengthen the lead function of flight attendants, distribute available exits and plan evacuation routes for passengers more reasonable, and develop more effective evacuation procedures accordingly. To improve the accuracy of computer simulation algorithm on emergency evacuation, here is an example. In nowadays algorithm, passengers are set to choose the nearest exit, and leave from this exit. Hence the computer calculating results often show the unbalance between passengers and exits, i.e., some exits are congestion, meanwhile some exits are underutilization. According to the results of this paper, passengers tend to choose the nearest exit at the first time, but when they face congestion, most of them would like to choose another exit and route. So, if the available exit can be distributed to passengers more reasonable, combined with the guide of flight attendants, then the passengers’ number that passing each exit can be balanced better, hence reducing the total evacuation time. This idea can be added to the computer simulation algorithm. This is a kind of method to do so: for the situation that passengers queue in front of a certain exit while other exits are unoccupied, set passenger choose exit again, which also means distributing exit to passenger again. When the evacuation time difference of two exits is greater than setting value, repeat the step of set passenger to choose exit, until satisfy the condition (the evacuation time difference of two exits is no longer greater than the setting value). Finally the optimized distribution of exits for passengers can be obtained, and the number of passengers that passing each exits can be balanced. According to this calculated results, the exits distribution and the evacuation routes for passengers can be designed more reasonable, and thus to minimize the total evacuation time and achieve more efficient evacuation.

References