Exit Choice Behaviour during the Evacuation of Two Lecture Theatres

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ABSTRACT

The pattern of movement to exits in two lecture theatres during a monitored evacuation is examined. The research study focuses on exit choice behaviour: the distance, direction and time taken to leave a setting in which there is an entrance and emergency fire exit. The front (F) lecture theatre studied has both of its exits at the back. In contrast, a nearby (R) lecture theatre, has the same design except that the entrance is in one corner at the back and fire exit towards the front. In the F theatre, 55% of the 56 people left via the main entrance, 45% via the fire exit. 88% of the individuals monitored left within 2.5 minutes. The pattern of movement, distance covered, exit used and time to leave by the different exits in the F theatre, were statistically analysed in relation to initial seat position. Under instructions from the lecturer everyone in the R theatre left by the fire exit. 70% of the total of 77 people left within 2.5 minutes. The exit choice behaviour is discussed in relation to the 2.5 minutes safety margin, the lecture theatre layout, different exit locations, verbal instruction from the lecturers and normal entry to and egress from the theatres.

INTRODUCTION

Despite the fact that major theatre fires during the late 19th and early 20th century have been such a significant catalyst behind the introduction of fire legislation (1, 2), scientific research of the patterns of human behaviour in theatres has been minimal. The lack of research data about the direction, distance moved and time it takes people to escape from an assembly setting is particularly

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pertinent in relation to the two and a half minutes conventionally recommended for travel to a place of relative safety in UK regulations and the principle of exit choice (2, 3). The origin of the two and a half minutes yardstick as the basis for calculating travel distance, exit width and location in relation to a discharge rate of 40 persons per minute, seems to be the Edinburgh Empire Palace fire in 1911, where evacuation evidently took about two and a half minutes (3). No research details of the timing of people's escape or the direction of movement can be traced. The principle of exit choice in public buildings such as cinemas and theatres has been adopted in the fire legislation of many countries. Exits should be spaced to allow people from different parts of the building to leave in an emergency. Equally important is that in the event of one of the escape routes becoming obstructed by smoke or flames, people can escape via another route. The aim of the study presented in this paper is to provide insight into the pattern of behaviour of people in a lecture theatre setting with an exit choice. By relating a study of movement in situ, to research on exit choice decisions in fires and realistic simulations (4), it becomes possible to effectively validate safety design solutions and emergency evacuation procedures. A particular feature of the study presented is a measure not only of the direction of people's movement but time to evacuate.

PREVIOUS RESEARCH ON EXIT CHOICE BEHAVIOUR

Empirical studies of exit choice behaviour, although recommended (5), have been rare. In one study (6) the sixth floor of a department store was used as the setting for a field experiment in which the outbreak of a fire was simulated by a rotating lamp and whistle. The number of fire fighter subjects running to each of five possible staircase exit routes was predicted using alternative formulas based on (a) stair width (b) distance to staircase and (c) visibility of stair entrance. The estimation based on visibility was most accurate. This study highlights the fact that proximity to an exit is not necessarily the primary determinant of its subsequent use. While the experiment is unique in exploring patterns of exit choice behaviour in relation to architectural parameters, it did not examine the degree to which social-psychological factors such as role or familiarity might be crucially predictive variables in an emergency. A case study of a large office fire (7) found that the choice of evacuation route, while influenced by amount of smoke, was also more likely if the evacuee regularly used the particular route. A similar pattern of movement was evident in the Summerland fire, UK. A detailed study found that 72% of people left by the familiar main entrance route into the building (8). A statistical appraisal of exit choice behaviour in one area of the building, the Marquee Showbar (9), revealed that all but one of the staff left by their everyday route into the building, the rear fire exit in one corner of the room, rather than the entrance in the other corner which was more familiar to the public.

Highlighted by research to date is the potential importance of familiarity of route, location and, not only the 'time to' escape, but the 'timing of' escape (9, 10). Unfortunately, it has been impossible in the retrospective field research of fires to measure the time it takes people to escape. In an attempt to reduce this gap in our knowledge, the focus of the study reported in this paper is not only on where people move, but when they reach exits during an evacuation. In exploring the time to reach exits in a lecture theatre setting,

several related hypotheses will be tested:

Hypothesis 1
Everyone will leave by the entrance

Hypothesis 2
Everyone will leave by the fire exit

Hypothesis 3
People will leave by the exit they are nearest to

LECTURE THEATRE SETTING

Figures 1(a) and 1(b) illustrate the lecture theatre design selected for study. The F (front) lecture theatre and R (rear) lecture theatre are located on the ground floor of a seven storey building in Portsmouth Polytechnic, England. Each theatre offers people a conventional exit choice, between the entrance and alternative emergency exit (with a 'Fire Exit' sign). Each emergency exit has a push bar which enables it to be opened from the inside and not the outside. In both lecture theatres there is a gradually sloping incline from the back to the front of the rooms. Both theatres are of exactly the same design except for the positioning of the exits. In the front F lecture theatre both the entrance and fire exit are at the back (figure 1(a)). In the rear (R) lecture theatre the entrance is in one corner at the back and fire exit towards the front on the same side (figure 1(b)).

While the distance to the nearest exit in both theatres is consistent with UK fire regulations, the positioning of exits in F lecture theatre would generally be deemed unsafe. Should there be a fire originating in the projection room both exits could be blocked. The width of each lecture theatre is 8.56 metres and the length is 10.47 metres. The fire exit doors are 0.76 metre wide in both theatres. The entrance in F lecture theatre is 0.80 metre wide and in the R lecture theatre, with double doors, is 1.30 metres wide. Both fire exits lead directly to the outside. The F fire exit and entrance are next to the main entrance to the building. The R entrance leads back into the building not far from another fire exit at the side of the building.

THE RESEARCH PROCEDURE

By prior arrangement with the safety representatives in the building we decided to monitor the behaviour of people leaving the lecture theatres during an evacuation of the building. In this evacuation none of the first year biology and pharmacy degree students (average age approximately 18-19 years old) had been in an evacuation of the building before, or were informed beforehand that an evacuation was going to take place. The research procedure was an extension of a methodology derived from previous evacuation studies of Canadian and Australian office blocks (11, 12). As each evacuee crossed the threshold of a doorway, an observer called out a number (starting from 1,2,3 etc) which corresponded to the number on a questionnaire sheet handed to the evacuee. Each number recorded on tape was subsequently converted into a time from the onset of the alarm. Using each evacuee's identity number, the evacuation time was individually matched against the questionnaire responses. Meanwhile an observer in

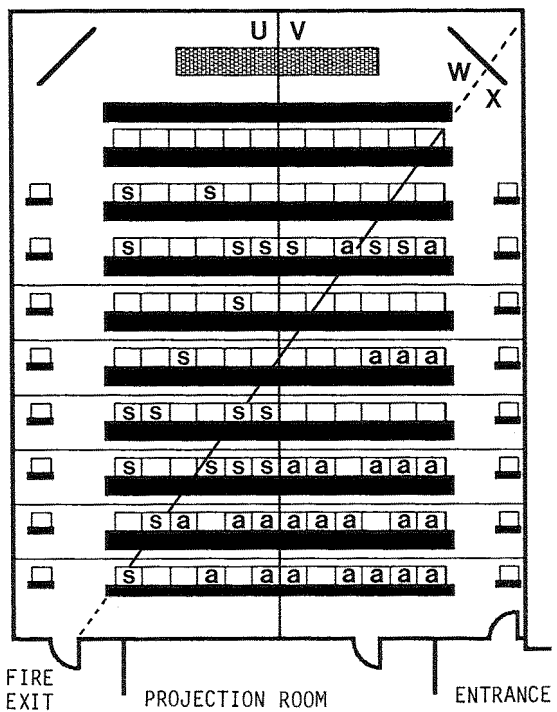


Figure 1(a) Front Lecture theatre: Individuals leaving by each exit in relation to seat and seating zones occupied. s = used fire exit, a = used entrance

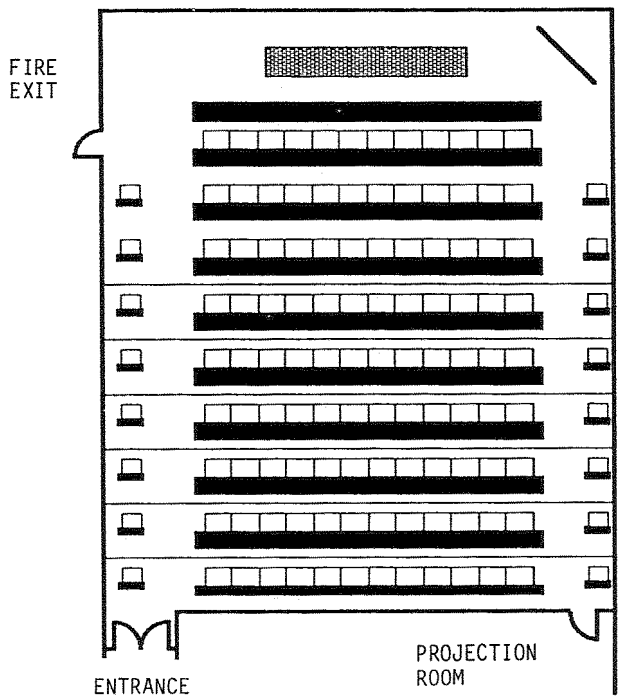


Figure 1(b) Rear Lecture theatre

scale in metres

0 1 2 3

each lecture theatre unobtrusively recorded each lecturer's response to the alarm. Evacuees were required to individually fill out the short questionnaire and hand it back to an observer who remained standing next to each exit. The questionnaire included a plan of the lecture theatre. Each evacuee was required to tick the box representing his or her seat location and draw on the plan the path followed to reach a theatre exit.

RESULTS

(a) Front Lecture Theatre seating position and exit used

At the time of the alarm, 56 people (excluding the observer) were in the F lecture theatre. 31 individuals (55%) left by the entrance and 25 (45%) by the fire exit. Thus, hypotheses 1 and 2 can be immediately rejected. The lecturer did not direct people to a specific exit. When the bell rang he paused for 3 seconds, continued a sentence from his lecture for a further 8 seconds, paused for 2 more seconds, then muttered, 'We'd better all run for exits.' As the general movement began he leant forward to talk to a student on the second row. 25 of those people leaving by the entrance and 24 of those by the fire exit (25 + 24 =49) returned a completed questionnaire giving a very high response rate of (49/56 = 88%). Of the 49 in the sample, 45 marked down their seating position and path of movement. Figure 1(a) illustrates the positions of people who left by each exit. Drawing a dividing line UV down the centre of the room and analysing the exit use by those seated on the fire exit side U, or entrance side V, is equivalent to a test of hypothesis 3. Analysis of the data in table 1 confirms this hypothesis (chi-square 16.28 $p < .001$ 2 tail). All except 8 individuals went to the exit they were nearest to. An analysis of seat position on either side of diagonal WX (figure 1a) produced comparable results (chi-square 14.35 $p < .001$, 2 tail).

TABLE 1 Front lecture theatre exit left by in relation to seating area U or V occupied = Hypothesis 3.

	Area U	Area V
Used Fire Exit	17	3
Used Entrance	5	20

(b) F theatre: Time taken to leave via the fire exit or entrance

Table 2 indicates the numbers of people who left within half minute intervals via the fire exit or entrance. It is clear that movement via the entrance began first. 68% of those using the entrance left by one and a half minutes and 96% by two minutes. In contrast, movement out via the fire exit did not begin until after one and a half minutes had elapsed. Of the total sample of 49 individuals, 88% had left by the time two and a half minutes had elapsed. A chi-square test of the frequencies in Table 2 reflected the fact that those using the fire exit generally left later than those using the entrance (chi-square = 29.9, $p < .001$, df = 4, 2 tail).

TABLE 2 Numbers of people leaving the Front Lecture theatre within different half minute intervals from the alarm bell sounding (N = 49).

	TIME FROM ALARM				
	(1 min)	(1 min 30)	(2 min)	(2 min 30)	(2 min 30+)
FIRE EXIT	0	0	9	10	5
% (cumulative)	(0)	(0)	(38)	(79)	(100)
ENTRANCE	4	13	7	0	1
% (cumulative)	(16)	(68)	(96)	(96)	(100)
combined cumulative frequency	4	17	33	43	49
combined cumulative %	(8)	(35)	(68)	(88)	(100)

The first person left at 47 secs
The last person left at 3 mins - 1 sec

(c) F Theatre: Interrelationship between seat location, distance moved, exit used and theatre evacuation time

An analysis was next carried out on the relationship between the following four variables (and subcategories):

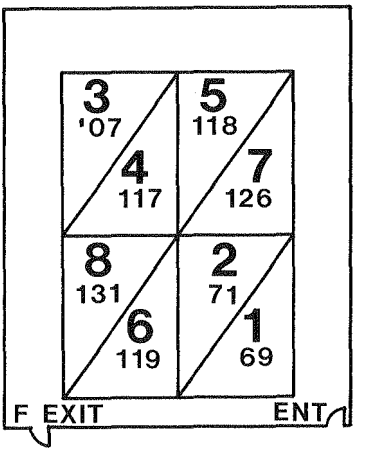
A seating area (A1 = W/A2 = X)
B distance moved (B1 = 8.56 metres or more/B2 = less than 8.56 metres: the width of the theatre)
C exit used (C1 = fire exit/C2 = entrance)
D theatre evacuation time (D1 = 'late' more than 2 mins /D2 = 'early' up to 2 mins)

Assigning each of the 45 people in the sample to one of 16 possible combinations of the above subcategories of A x B x C x D, revealed that approximately half (49% = 22/45) were characterised by one combination: A2B2C2D2. This represents the cluster of people who were seated towards the entrance corner, who exited in a homogeneous fashion, unimpeded, via the entrance, before everyone else. The remaining 23 people were spread across the range of combinations of A x B x C x D. A hierarchical loglinear analysis (13) was carried out on a table of frequences for A x B x C x D. The simplest statistical model fitting the data was (AC)(CD)(BC)(AD), (likelihood ratio chi-square = 2.46, df = 7, p = .93). The likelihood ratio chi-square changes (L.R.C.) confirm that the strongest associations were between pairs (AC): L.R.C. = 22.6, p <.001, and (CD): L.R.C. = 22.6, p <.001.

A three-way analysis of variance was next carried out on A, B and C as independent variables and D, time to evacuate as the dependent variable, using the actual distances moved and time to leave in the analyses. This reproduced a significant main effect CD ($F = 25.3$, $df=1, 38$, $p <.001$), but also an interaction between ABD ($F = 5.7$, $df=1, 38$, $p <.02$). What the interaction shows is that the first people to leave the F lecture theatre were those in area X located

nearest the entrance. Following their departure were people from seating area W located furthest from the entrance. People from area W located near the fire exit left next via the entrance, followed by people from area X located furthest from the entrance. The individual paths of movement drawn indicate that the travel distances moved were equivalent to travel distances to the exit left by. Figure 2 summarises in further detail the pattern of relationships between seating area location and time to leave, indicating that the last individuals to leave were located near the fire exit.

Figure 2 Order of egress in relation to 8 seating zones and average evacuation time in seconds (lower number in each triangle)



The majority of people (75.6%) recorded that the exit they chose to leave the F lecture theatre by was determined by it being the 'nearest exit'. A chi-square analysis indicated that those using the entrance, as opposed to the fire exit, were most likely to cite 'nearest exit' as a reason for their exit choice (chi-square = 3.97, $p < .05$, df=1, 2 tail). Of the 8 people giving 'other reasons' for leaving by the fire exit, the reasons were various: 'sign said fire exit' (N=3), 'quickest' (N=3), 'led straight to outside of building' (N=1), 'less congested' (N=1). Of 3 people who did not mention 'nearest' as their reason for leaving by the entrance, the reasons were as follows: 'followed other people' (N=1), 'people obstructing the fire exit' (N=2).

(d) Rear Lecture Theatre

The results presented concentrate primarily on the pattern of behaviour in the F theatre. This is partly because the pattern of evacuation in the R theatre was exclusively to one exit. This precluded a set of statistical analyses comparing the degree to which certain factors appear to have drawn people to each of two exits. In addition, some difficulties were experienced by the observer at the fire exit in individually handing out the questionnaires without disrupting the traffic flow (a characteristic of the research

procedure to be amended in a future study). After 67 individuals had left and been given questionnaires, he estimated that a further 10 individuals came out, making 77 in all. Precise exit times for these 10 were not registered. The response rate in terms of completed questionnaire returns was 43% (33/77), somewhat lower than that for the F theatre where evacuees from the whole building collected nearby.

In the R theatre everyone left by the fire exit at the front of the room (hypothesis 2). This is explained by the actions of the lecturer, who continued the lecture momentarily. He then went over to the fire door and announced 'I gather it sounds like a fire alarm. Have to go that way', (he pointed to the fire exit). He stayed by the fire exit encouraging people to move out through the door. Of the 32 respondents giving their reasons for using this exit, 9 (27.3%) said it was the 'nearest exit', 12 (36.4%) that they were 'told to use it'. Each of the following reasons was given by 2 or 3 of the other 11 people: 'followed the people', 'quicker', the 'fire exit sign', 'led straight to outside of building', 'because the door was open'. The further away people were from the fire exit the longer they took to reach it; (ie there was a significant correlation between distance and time: $r = 0.68$, $p < .001$. Combined with the paths of movement drawn by people, the results reflect an orderly progression toward the fire exit, with those towards the back of the R lecture theatre and furthest from the fire exit following those in front. Of the 77 people estimated as present, 70% had left by the time two and a half minutes had elapsed.

DISCUSSION

Although the present study did not have a fire or smoke threat, it was possible to examine the exit choice behaviour in relation to an alarm siren (often the first indication of a fire). The fact that the majority of people exited within two and a half minutes in both lecture theatres is reassuring. However, the acceptability of the two and a half minutes safety margin in UK regulations should undoubtedly be studied further. We do not know the effect of an increase in the numbers of people seated to the full capacity of 124, and the time it would take for this number of people to leave by one or two exits in the theatres. If two and a half minutes is to be regarded as a safety margin in a variety of occupancies, it should allow for the slower response of a less homogeneous audience, with cohesive social groups, a wider range of ages and physical mobility, moving in less familiar surroundings and towards more inaccessible final exits from a building. Moreover, the two and a half minutes safety margin in UK fire legislation is based on the time to move and not the timing of escape as well (ie time to react to an alarm and start moving) (10). Response to an alarm siren may vary with the type of building population and the nature of the information available about a threat.

Perhaps the main insight provided by the study of the F theatre is into the subtle relationship between choice of seat location, seat layout, proximity to a normal entry route in regular use and time to escape. Previous research of seat selection during lectures (14) suggests that as in this study, people will be predisposed to sit in rows towards the back of a room, rather than the rows immediately in front of a lecturer. As a consequence, the majority of occupied seats were at the entrance and fire exit end of the F theatre. The paths to exits drawn, suggest that the exit used was determined the moment he

or she decided to move to the left or right from a seat. Movement was along each row and then down an aisle with no-one passing by one exit, in favour of the other. Clearly, the position of a person on a particular row, and numbers of people encountered in the seating aisles, will have restricted access to the exits for some people more than others. The first people to leave were those located in the seating area nearest to the entrance, who left much more rapidly than others via that route. People in the seating zones moving third, fourth and fifth (figure 2) evidently decided to go to the fire exit as an alternative to the entrance which was already being fully used. As the time elapsed those remaining in the sixth and seventh zones, perhaps drawn psychologically towards the entrance, were free to leave by the right aisle and follow those nearer to the entrance leaving that way. Those in the eighth zone evidently had to wait until other people using the left aisle had passed, before going to the fire exit.

The fact that everyone in the R lecture theatre left by the fire exit, as a result of the lecturers instruction, demonstrates how crucially important evacuation instructions from an authoritative and credible source can be. However, the likelihood of the lecturer directing people to the fire exit is likely to have been strongly influenced by the position of the exit and the normal pattern of entry and egress before and after lectures. Unlike the F lecture theatre, the R fire exit is often used by students when leaving at the end of the lecture, so as to avoid congestion at the R theatre entrance from incoming students, and to provide a short-cut to the next lecture. The fire exit in the R lecture theatre is also situated very near the lecturing position, in full view of the audience.

The present study is not definitive in predicting what would happen in all seated assembly settings and circumstances. However, the study does suggest that while proximity to an exit does influence the timing and direction of escape from an assembly setting, it does not determine it in an absolute fashion. People's exit choice behaviour in drills and emergencies seems to be closely related to the normal patterns of circulation and the configuration of exits. Encouragement to use a fire exit route, by virtue of its location, regular use, and guidance towards it during an emergency, will increase the chances of it being promptly used when it is most needed. When this study is compared with statistical analyses of behaviour in fires (8,9), it suggests that people's location, familiarity with routes, and the pattern of social communications prior to and during an evacuation, crucially influence the direction and timing of escape. Fire design legislation and complementary evacuation procedures need to pay greater attention to these social-psychological factors, if people's safety is to be effectively assured.

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