Passengers' behaviour during an underground evacuation

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Abstract

A study was conducted to assess the impact of different types of information on people's behaviour when evacuating from an underground station. Five evacuations were conducted at Monument Station which is the most complex underground station within the Tyne and Wear Metro network in Newcastle, United Kingdom. For each of the five evacuations, the information and the means of providing the information differed: E1- alarm bell only, E2- alarm bell with two staff members, E3- alarm bell and minimal non-directive public announcements, E4- alarm bell with two staff members and directive public announcements, E5- alarm bell with improved directive public announcements. During the evacuation, twelve video cameras and seven observers in the setting recorded the passengers' behaviour in all spaces of the station. Analysis showed that the passengers' behaviour varied depending on the information provided. Evacuations 4 and 5 proved to be the most successful at prompting appropriate responses.

Introduction

The management of safety in public buildings is given the highest priority by decision maker. Recent tragedies that occurred during the evacuation of hotels, stadiums and underground spaces support the fact that there is an urgent need for improving the organization of safety and security in public places. One of the major preoccupations in managing safety is indeed the interaction between the space, the emergency situation and the people. Although staff and a whole range of technical devices such as public announcement systems are usually available to inform people about the situation, management team seem reluctant to provide information. In fact, safety plans often suggest not to inform people if an incident has occurred as long as an evacuation is not necessary. In the eventuality of an evacuation, a fire alarm bell is activated and users must move toward a safe area. Even if many managers suspect that their communication system could be used more efficiently, the assumption that "panic" would occur if people were aware of the situation prevents them from providing the information.

The Tyne and Wear Metro Executives, in collaboration with the Tyne and Wear Fire Brigade in Newcastle, United Kingdom, ordered this research to assess the usefulness of their communication system to evacuate an underground station. The people's reactions to the various information

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provided and the means by which this information was provided were tested.

People's behaviour in an emergency situation

Over the last thirty years, a large body of research has been developped on the subject of people's reactions during emergency situation and evacuation. One of the major findings is that people do not evacuate at the first cue of a potential emergency. Time is spent going over the processes of interpreting the information, preparation and action (Canter, 1985). When noticing cues such as a fire alarm bell, smoke, the smell of burning or people shouting, users of a public space will tend to ignore the situation or will look for more information. This implies that users will start their movement to evacuate some time after the first cue of an emergency situation. People will only start to move when enough information convinced them that they have to evacuate the building. The delay between the first cue of an emergency and the time to start to move is paramount because the time remaining to evacuate safely depends on a quick response of the people. The questions pertaining to how this delay could be reduced and how evacuation behaviour could be prompted remain crucial when it comes to mastering safety in public buildings.

Another important finding related to peoples' behaviour in an emergency situation is the occurrence of affiliative behaviours. In his analysis of movement, in the Summerland Fire, Sime (1985) demonstrated that people move toward familiar persons and places. Members of groups who were apart when cues of a potential danger occurred tend to react more rapidly in order to find the other members so that they can evacuate together. This early movement to find missing members of a group induces a quick start which could imply a quick flight from the dangerous area. In addition, affiliation implies moving at the group speed which tend to adjust to the speed of the slowest member. The time it takes to move toward safety for the entire group is therefore increased. Affiliative behaviour with places was also observed which predicted that people headed toward familiar route when evacuating from a building. Emergency routes being most often unknown and unused by the public were disregarded for more familiar routes and exits.

Although popular knowledge suggests that people "panic" during dangerous situation, studies in environmental psychology have proven that very little evidence exists with respect to a "panic" type of reaction during an emergency (Keating, 1982). According to the "panic scenario" people aware of a threat, such as a fire, would present irrational, animal-like behaviours competing amongst each other in order to escape by the same limited route. In fact, a close examination of people's behaviour during emergency situations showed a fairly different picture. Behaviours such as jumping, fighting to reach an exit or leaving without family members are extremely rare (Sime, 1980; Bryan, 1983, Wood, 1979).

Analyzing behaviours retrospectively, could demonstrate that the best reaction was not applied which does not mean that the behaviours were irrational. From the perspective of a person facing a threat, a behaviour could be judged as being perfectly sensible, whereas, for other people, or after the event, other options could appear as being more effective. Although people might feel some form of stress, their reactions to the threat could be explained within the limit of their knowledge on the basis of the alternatives and information available at the time of the situation.

Furthermore, the concept of "panic" used to explain people's reactions during an emergency is not a very constructive one for the purpose of research. If "panic" is likely to occur, it becomes useless to try to change such an uncontrollable type of reaction. On the other hand, admitting that people are capable of processing information and of making decisions during an emergency is more likely to stimulate research. This approach suggests that researchers could develop ways to communicate information to people to help them evacuate safely in the eventuality of an emergency.

Evacuation of an underground station

The management of safety in a public place is supposed to probe and update safety measures on a regular basis. Although well-planned and well-organized, fire safety procedures must be tested to ensure their practicability. The Tyne and Wear Metro Passenger Transport Executive on the advice of the Tyne and Wear Fire Brigade commissioned this research to assess the use of their particular communication system to ensure a safe evacuation of the public from an underground station (Proulx & Sime, 1989; Sime et al. 1990).

The Tyne and Wear Metro located in Newcastle U.K. is a public transport system comprising a network of 44 stations including 10 underground stations spread along four train lines. The system as been developed since 1980 and transports around 200, 000 passengers daily. Because a self-service ticketing system is used, Metro has no permanent staff at the stations. At concourse level, turnstiles delimit the "valid ticket area" and Revenue Control Inspectors (RCI) patrol around the network to check tickets and provide information and assistance. All Metro stations are accessible to wheelchair users through lifts from street level to platform level, thus allowing a large amount of mobility impaired persons, elderly and people with pushchairs to extensively use the system.

The Control Room in the Control Centre building is the nerve centre of the system. Active 24 hours a day the Control Room comprises Train Controllers and Station Controllers. The Train Controllers are responsible for supervising safe and efficient train operations. A computer indicates all technical faults and an electronic board displays train movement thereby allowing the controllers to have a full perspective of the functioning of the train system. The controllers are in permanent radio contact with all train drivers, who in turn, could give public announcements (P.A.) to their passengers. Station Controllers are responsible for station technical operations, passengers information and safety. When a technical failure in a station is detected, it is transmitted to a computer which alerts Station Controllers who dispatch the information to the appropriate technicians. Cameras located in each station allow the controllers to watch passengers on closed circuit TV screens. A public announcement system is available to give messages directly to a specific area within a station, to the whole station or to all stations. The interactive access to the computer, to the cameras and to the public announcement system, enables Stations Controllers to have a complete overview of the environment and, accordingly, to give precise messages to all users. A local public announcement system and an electronic board are also located in each station. Staff members and firemen can consult the board to locate a technical failure and use the handset to give messages to the station users.

This privileged organization of communication between the staff, the environment and the users was tested to assess the efficiency of the system to ensure a successful evacuation of the public.

In order to perform the experiment, Monument Station was chosen for two main reasons. Firstly, Monument Station is the busiest and the most spatially complex station of the network with; three entrances, three underground levels, four platforms, two sets of escalators, a staircase and two lifts, (See Figure 1). Secondly, Monument Station has a spatial organization resemblance, on a smaller scale, to King's Cross Station in London. Both stations have two sets of escalators leading up to the concourse. In the eventuality that one set of escalators may be blocked, the other set can be reached by using an alternative route. To some extent, the King's Cross disaster acted as a framework to

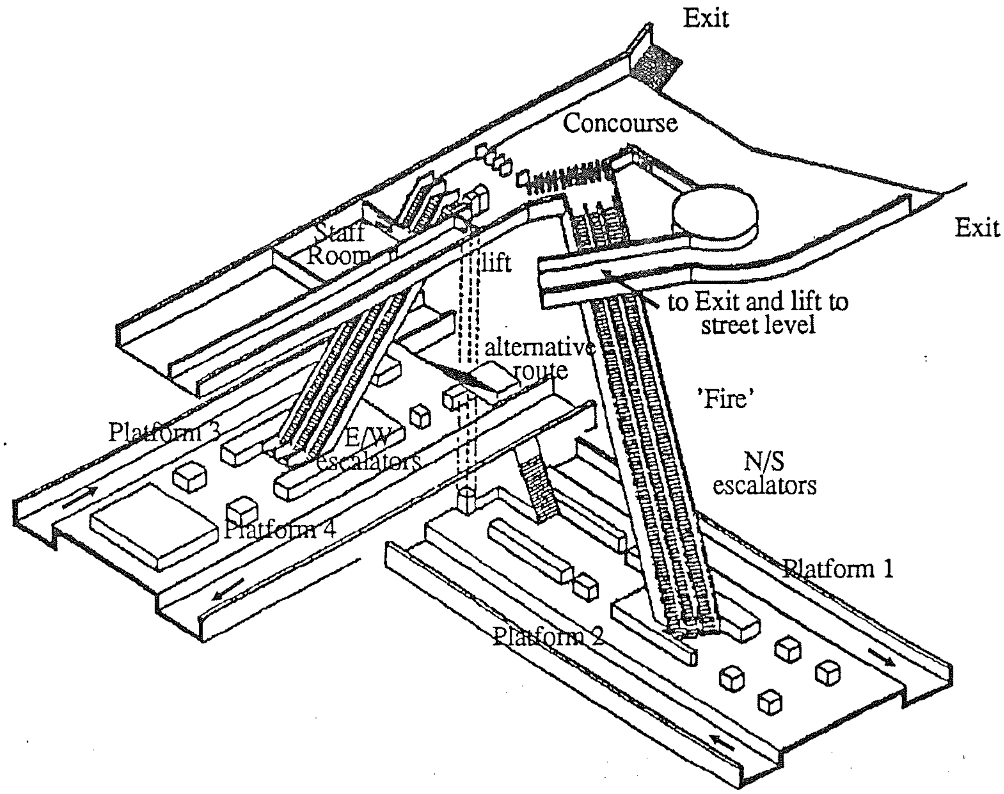


Figure 1: Monument Station

develop the Monument experiment because reports explained the development of the fire and smoke and the behaviour of people (Fennell Report, 1988; Donald & Canter, 1989). The King's Cross underground station was the site of a fire on November 18, 1987. In short, some time after 7 p.m. a fire was discovered on the Piccadilly escalators leading up to concourse area. A fire alarm was turned on, but the public address system was not used. Passengers disembarking from arriving trains were directed through an alternative route to the Victoria escalators landing up to the concourse where a dense black smoke and flashovers occurred; 31 people died in that fire. The "fire" for the Monument experiment was located on the North/South escalators just as it was on the Piccadilly escalators in the King's Cross disaster.

A fire scenario was set up for the experiment which remains the same for the five evacuations. The evacuation procedures were coordinated from the Control Room with the participation of various staff members from the Metro and the local Fire Brigade. The passengers were not aware that they were participating in an experiment.

The starting time for the experiment was synchronized with the train schedule in order to have the same train arrival pattern at Monument Station for each evacuation. The cue to start the exercise was the departure of train 124 from Haymarket Station going to Monument Station. Simultaneously, a Station Controller called two technicians hidden underneath N/S escalators who, activated a smoke detector with a long lighting stick. The activated smoke detector automatically drove a failure cue to the control room computer and the station electronic board sounded the fire alarm bell and lighted the "Fire do not enter!" signs located at the three entrances and on top of the two escalators sets. When the alarm sounded, four firemen in uniform, who had been waiting in the staff room, took their positions. Two firemen were located at the top of the N/S escalators and two others were located at the bottom of the escalators. After turning the power off of the escalators, the firemen prevented people from using them, and when asked any questions they simply answered "Please evacuate the station". When train 124 stopped on Platform 1 at Monument Station, the alarm rang and five seconds later, one of the five experimental procedures took place :

<u>E1</u> : The alarm bell sounded. No staff and no public announcement took place in this evacuation.

<u>E2</u> : Two Revenue Control Inspectors (RCIs) performed this evacuation. The two RCIs that were chosen had been working for Metro for more than two years. They knew a fire exercise would occur and were standing on Platform 3. When they heard the alarm, they contacted the Control Room for information by using the emergency button on their radio. This is the procedure they learned in safety training. They were instructed by the Station Controller: a) to verify the electronic board to determine the location of the activated smoke detector, b) to give a P.A. "to evacuate the station" through the local public announcement system, and c) to direct the evacuation of all passengers: the Control Room being in the impossibility to assist the evacuation they were going however to contact the Fire Brigade.

<u>E3</u> : Five seconds after train 124 arrived, the Control Room gave the P.A. "Please, evacuate the station immediately. Please, evacuate the station immediately.". This P.A. was repeated at 20 second intervals. This message is minimal and non-directive. No staff members were present during this evacuation.

<u>E4</u> : Two RCIs and the Control Room in full operation conducted this evacuation by following planned procedures by Metro. The two staff members were the same ones as in E2 and the starting procedures were identical. When contacting the Control Room, the RCIs received instructions to assist the evacuation and to fellow indications given by the P.A.s. The Station Controller gave directive P.A. requesting passengers on platforms to board the trains and the ones on the concourse to leave by the exits.

<u>E5</u> : The Control Room was in full operation and gave directive P.A.s. No staff members were present. The P.A.s for this evacuation were different from the ones in E4 because the information given to the users referred to the incident; the type of incident, its location and what was expected from the users. The first P.A. wording was, "To all passengers. There is a suspected fire on the North/South escalators between the concourse and Platforms 1 and 2. Passengers on all platforms should board the first available train. Passengers at concourse level should leave by the nearest exist. Do not use the lift' (repeated).

While the alarm sounded, train drivers and passengers of the first arriving train at each platform received no specific information. Drivers of the following trains were called by the Train Controller when they arrived at neighboring stations. The drivers were informed to give a P.A. telling their passengers not to disembark at Monument because the train would stop to pick up passengers only. The Fire Brigade was contacted by a Station Controller four to five minutes after the beginning of the exercise. When the firemen arrived, they checked the location of the suspected fire on the electronic board. Some verified this information whereas others evacuated the station. The fireman who was responsible for the operations gave the 'All Clear' message as he resets the electronic board which stopped the alarm bell and the "Fire do not enter!" signs. The evacuation was over.

This procedure was exactly the same for the five evacuations: the only thing that varies was the content of the information and the means by which the information was provided. The evacuations were conducted during the same week at mid-day at 12:18 or 14:18. Previous surveys indicated that during these time periods, the same average number of passengers used the station. The twelve cameras at Monument were coupled to video in order to record each evacuation. Seven observers were posted in areas of the station that were not covered by cameras. With the help of a handed tape recorder, observers counted the users who went up and down stairs and escalators as well as those who went in and out of entrances and lifts.

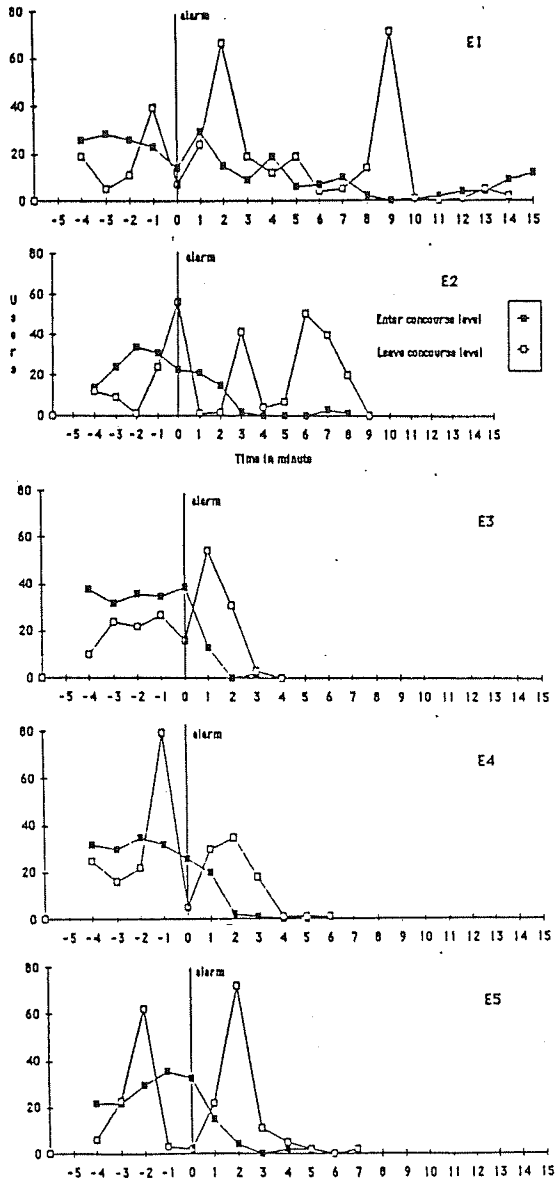
Passengers' behaviour

The twelve videos and seven observers started recording the passengers' behaviour five minutes before the exercise up until the 'All Clear' given by firemen. These data recording procedures allowed for the exceptional opportunity to precisely analyze each passenger's behaviour throughout the entire evacuation. In summary, the most common behaviours that were noted during each evacuation have been divided into three categories. Graphs 1 : Enter the concourse and Leave the concourse, Graphs 2 : Wait for a train, Wait at concourse, Wait at the bottom of N/S escalators, Graphs 3 : Get on a train and Get off a train, (see following pages).

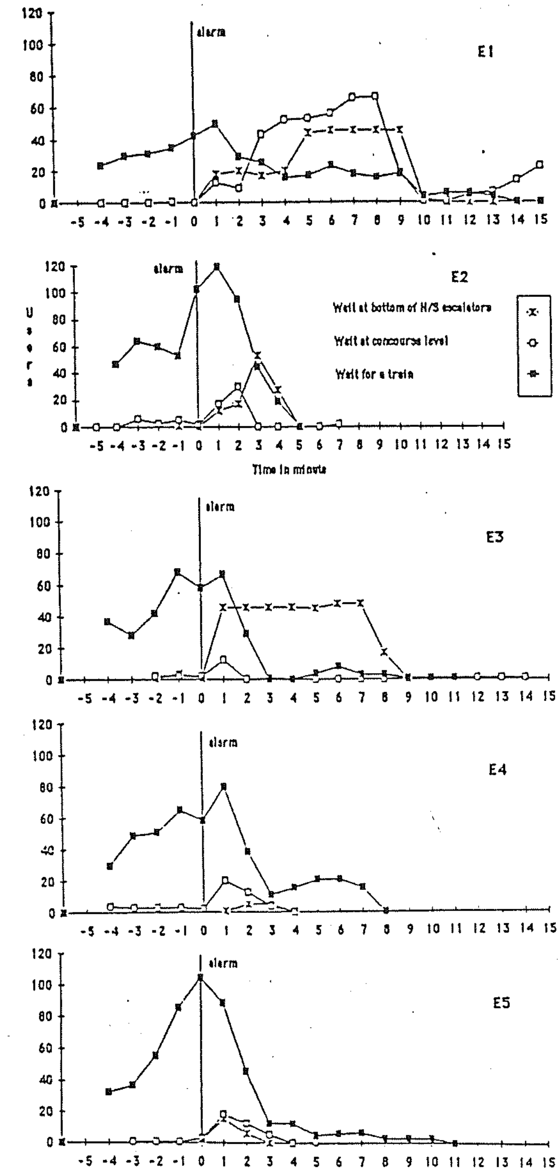
According to the spatial organization of Monument Station, the location of the "fire" and with respect to what is known from the King's Cross disaster, the more appropriate passenger behaviours could be extrapolated. When hearing the alarm and seeing the "Fire do not enter!" signs, people coming from the outside should not enter the station and those at the concourse level should leave by the nearest exits. Passengers on all platforms level should board the next available train and passengers on trains should not disembark. Only people who are evacuating by a train shoud be waiting.

Results have shown that there is a different pattern of behaviours, in time, for each evacuation. The evacuation E1, with alarm bell only, is typical for is non-evacuation behaviours. People continued to enter the concourse until the firemen arrived and stopped them at the entrances 8 minutes after the alarm was sounded. Although some people entered the concourse and turned back to leave, the majority stayed at concourse level and gathered into a group of 43 to 66 people and waited near the turnstiles. This crowd was moved out by the firemen 8 minutes after the alarm was sounded. During that time, at the lower level, a crowd of 45 passengers were waiting at the bottom of N/S escalators and was prevented from going up by the two posted firemen. This crowd was instructed by arriving firemen to evacuate by train 9 minutes after the alarm. Meanwhile, passengers on the platforms

Graphs 1: To Enter and to Leave concourse level



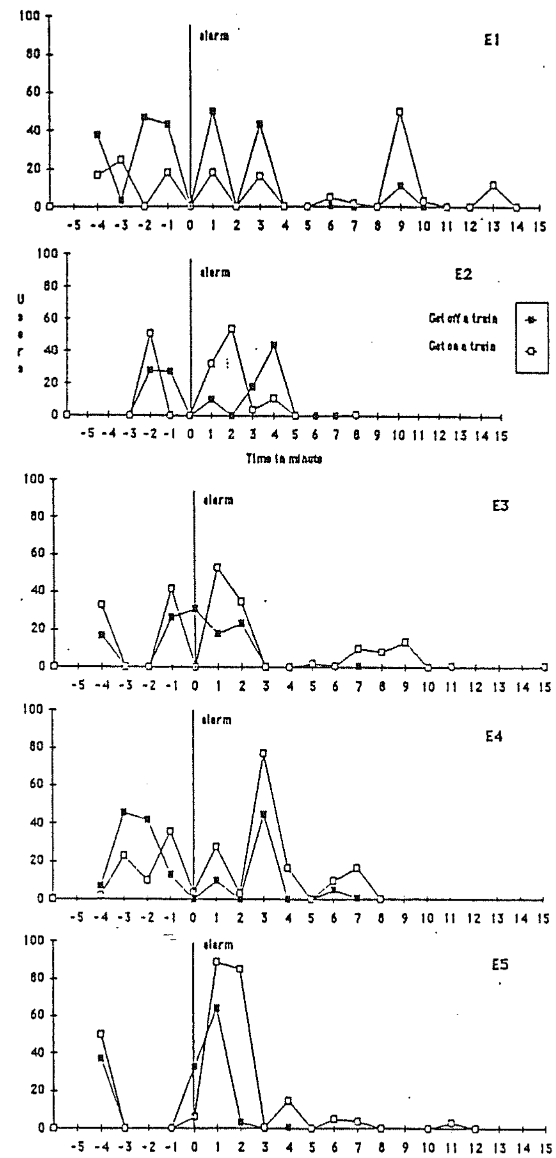
Graphs 2: To Wait at bottom of N/S escalators, to Wait at concourse level and to Wait for a train



continued to wait for trains and to get onto the trains. Out of 109 passengers who got off a train after the alarm, only one got back onto the same train. The station was never totally cleared. When the firemen went down at the lower levels to evacuate passengers, newcomers continued to enter the concourse.

In E2, the two RCIs mastered an energetic evacuation. As planned, at the sound of the alarm, they contacted the Control Room with their radio and ran upstairs to the concourse level to check the electronic board to determine the location of the activated smoke detector. With the local public announcement system one of the RCI gave an unclear P.A. being out of breath. This RCI remained at the concourse level and prevented people from entering or waiting inside the station. This was effective, 3 minutes after the alarm the concourse was cleared. During that time, the other RCI raced to the lower levels to evacuate passengers. All passengers who were on platforms or who were waiting at the bottom of the N/S escalators, were directed to leave the station from the concourse by the alternative route. The lower levels were cleared 5 minutes after the alarm. The RCI ran from one platform to another to prevent passengers from getting off the trains. Although this evacuation was very rapid and people responded immediately to RCIs directives, the evacuation route that was chosen was not the safest one with respect to the location of the "fire". Passengers were still crossing the concourse to evacuate up to 9 minutes after the alarm.

Graphs 3: To Get On and To Get Off a train



The evacuation E3, with the repeated P.A., "Please, evacuate the station immediately", appeared to be much more efficient then the E1 with alarm bell only. Indeed, 3 minutes after the alarm people stopped entering the concourse area and a small waiting crowd of 13 people left by themselves. During that time, the passengers on the platforms got onto the arriving trains. Only 45 people got off a train from which 7 jumped back after hearing the P.A. Nevertheless, a large crowd of 48 people gathered at the bottom of the N/S escalators and waited patiently for 8 minutes before being evacuated by the arriving firemen.

The evacuations E4 and E5 were the best evacuation of all. In E4, the joint efforts of two RCIs and the directive P.A.s allowed for a rapid and efficient evacuation. One RCI remained at the concourse level, evacuated a small waiting crowd and stopped people from entering. Four minutes after the alarm the concourse was cleared. Meanwhile, the other RCI, in accordance with the P.A.s cleared a small crowd at the bottom of N/S escalators and directed disembarking passengers back onto the train. Out of the 61 passengers who got off a train after the alarm, 44 went back into the train. The remaining passengers waited and were evacuated by another train.

The improved directive P.A.s of E5 proved to be very efficient and very rapid. Despite the fact that no staff members were present, the precise P.A.s themselves were successful at handling the evacuation as planned. As instructed by P.A.s people stopped entering the station and a small crowd of 19 people left the concourse. This level was cleared 3 minutes after the alarm was sounded. At the platforms level, all 68 passengers who got off a train went back onto the same train as instructed by P.A.s. At the bottom of the N/S escalators, a small crowd of 16 people who heard the P.A., "There is a suspected fire on the North/South escalators..." left the area immediately to wait for a train on a platform. As instructed a few passengers waited for a train to be evacuated for as long as 10 minutes after the alarm.

Discussion

The five evacuations showed a different picture depending on the information provided to passengers. The evacuation E1 with alarm bell only, did not instigated evacuation behaviours. Passengers continued their usual routine which consisted of going in and out the station although the firemen blockage of the N/S escalators created a crowd of waiting passengers. This crowd waited patiently for as long as 10 minutes before they were moved by the arriving firemen. These behaviours suggest that the situation was not judged threatening by passengers and the alarm bell was not enough to compound this lack of environmental threat and motivate evacuation behaviours. In E2, the RCIs demonstrated that they were capable of instigating an early movement to evacuate. The main problem related to staff members who try to direct an evacuation is that while the passengers are being evacuated from one area, there are always people somewhere else coming in. This lack of overview of the situation and of the space thwarts the effort of controlling the evacuation. Furthermore, if the development of the experiment "fire" would have been like the one of King's Cross, the 61 passengers directed by the RCI to the concourse area would have had their lives threatened. Surprisingly, the evacuation E3 were there were limited P.A.s proved to be a major improvement to the simple alarm bell of E1. In fact, except for the waiting behaviour, the minimal P.A.s succeeded in stopping people from coming in and encouraged passengers to leave the station by exits and trains. Nevertheless, the crowd which gathered at the bottom of N/S escalators remained there until the arriving firemen moved them. This observation supports the theory of affiliative behaviour with places: people try to evacuate by their familiar route. During the evacuation exercise, the familiar exit route was blocked, passengers did not try to find another route and waited patiently for more information. Under those circumstances, the P.A. messages were not enough information to incite the passengers to look for an alternative route to evacuate nor to get back onto a passing train.

As expected E4 and E5 were completed rapidly and efficiently. This is not surprising for E4 where staff and directive P.A.s worked together to conduct the evacuation. In E5 the P.A.s explaining plainly the situation did not provoke a "panic" or non-appropriate behaviours as some managers had feared. The straightforward statement of a "suspected fire" acted as a booster to rapidly interpret the seriousness of the situation and to make the decision to evacuate as instructed.

Given the amount of investment the Monument station experiment contitutes a case study based on only five evacuations. Inferential statistics were not applied to interpret data because behaviours during each evacuation were interrelated. However the findings clearly demonstrated that information and procedure applied could change the course of an evacuation.

Conclusion

This experiment demonstrated that in order to make appropriate decisions in the case of an emergency people need precise information related to the nature and location of the incident and the behaviour expected from them. The "standard" alarm bell does not appear to be interpreted by users as an emergency message calling for immediate evacuation of the space. Different types of information and means by which this information is given are actually available to managers of public spaces. It is now necessary to establish the content of the information that could best support the behaviours expected from users. The plannification of safety procedures is a developing activity which needs to be improved and tested regularly in order to insure safety of the public in the eventuality of an emergency.

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